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UNITED STATES DEPARTMENT OF AGRICULTURE

REPORT ON
THE AGRICULTURAL EXPERIMENT
STATIONS, 1925



PREPARED BY THE
OFFICE OF EXPERIMENT STATIONS

OFFICE OF EXPERIMENT STATIONS

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RELATIONS WITH THE STATE EXPERIMENT STATIONS

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EXPERIMENT STATION RECORD

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UNITED STATES DEPARTMENT OF AGRICULTURE
OFFICE OF EXPERIMENT STATIONS

Washington, D. C.

October, 1926

REPORT ON THE
AGRICULTURAL EXPERIMENT STATIONS, 1925

By E. W. ALLEN, W. H. BEAL, and E. R. FLINT

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This report relates to the progress of the State agricultural experiment stations which participate in the Federal appropriations, for the year 1924-25. These appropriations are made under authority granted by the Hatch Act (March 2, 1887), establishing experiment stations in connection with the colleges of agriculture organized under the Morrill Land-Grant Act of 1862, and the Adams Act (March 16, 1906), increasing the support of these stations. The appropriations amount to \$15,000 to each State under each of the above acts, or \$30,000 annually, a total of \$1,440,000. Reference is also made to the progress of the experiment stations in the outlying Territories and possessions, Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands, for which direct appropriation is made by Congress, the stations to be under the immediate charge of the Department of Agriculture.

This report, like those of previous years, is submitted in accordance with provisions of the Federal acts which clothe the Department of Agriculture with certain administrative, supervisory, and advisory functions in relation to the stations, exercised through the Office of Experiment Stations, and require "an annual report to Congress on the receipts and expenditures and work of the agricultural experiment stations in all of the States and Territories."

The year was one of continued progress, but without material change or enlargement, as the stations had, for the most part, reached the limits of their resources. It was, however, notable for two events of very large importance to the experiment station system, namely, the fiftieth anniversary of the establishment of the first experiment station in the United States, and the passage by Congress of legislation which will ultimately treble the Federal support of the State stations and materially broaden their field of investigation. It was a fact worthy of special note that just 50 years after the beginning of the experiment station as a State institution in this country, Congress should give such substantial recognition of the place it has attained in the Nation.

ANNIVERSARY OF THE FIRST AMERICAN STATION

The pioneer experiment station in this country was established in Connecticut in 1875. Agitation over a considerable period for an experiment station on the model of those existing in Europe resulted in the passage by the State assembly, in July of that year, of an act appropriating \$2,800 per annum for this purpose for two years. The proposal aroused little interest on the part of the great mass of farmers, and this initial step was due rather to

friends of the measure who believed that if such a station could be established its usefulness would be so clearly demonstrated that it would be continued. Previous to that time there had been considerable investigation in the interest of agriculture in many of the States, notably at the agricultural colleges, and several of the latter had made some provision for it. The act of the Connecticut General Assembly provided for a definite, organized agency, which proved to be a permanent one, and has spread to the present national proportions.

While the growing use of commercial fertilizers and the need alike for their regulation and for a broader knowledge of the principles of their use were prominent motives in connection with the early stations, high ideals prevailed at the outset which did not permit their being developed as either exclusively control stations or left to the simpler forms of testing. The initial statement from the new station in Connecticut emphasized the absolute importance of abstract scientific investigation, and declared that "such an institution will be worthy of the name in proportion as it carries on thorough investigation and experiment in agricultural science." Two years later, when despite a severe financial depression the station was made permanent, the object of the appropriation was stated to be "to promote agriculture by scientific investigation and experiment."

This fiftieth anniversary was observed at the experiment station in New Haven, Conn., on October 12, 1925. The governor of the State presided and there were representatives from important agricultural and other organizations, the experiment stations of various States, and the Department of Agriculture, with greetings, congratulations, and appropriate addresses. The entire station system owes much to this initial step in Connecticut. The fact that the end of this half century finds the stations well established, definite in their aims, and with high ideals for their activity, is due in no small measure to the start made at the outset and the care and foresight with which the foundations of the movement were laid.

THE PURNELL ACT

The other outstanding event of the year was the passage of the Purnell Act, on February 24, 1925. This act, providing for the more complete endowment of experiment stations, was the culmination of a movement which had been in progress for several years. The

measure had the support of representative agricultural and business organizations throughout the land, as well as the Association of Land-Grant Colleges, which had presented the needs and the advantages to agriculture generally of enlarged support for research. The sentiment in favor of such additional Federal aid was crystallized in the President's Agricultural Conference, and had his indorsement.¹

The Purnell Act authorizes an appropriation of \$20,000 for the year ending June 30, 1926, with annual increments of \$10,000 thereafter until the total amounts to \$60,000 annually for each State. Under this authority the maximum would be reached in the fiscal year 1930. The act specifies that this money is to be used for paying "the necessary expenses of conducting investigations or making experiments bearing directly on the production, manufacture, preparation, use, distribution, and marketing of agricultural products and including such scientific researches as have for their purpose the establishment and maintenance of a permanent and efficient agricultural industry, and such economic and sociological investigations as have for their purpose the development and improvement of the rural home and rural life."

The new appropriations are applicable to the stations already established under the Hatch Act, and, like those under that act and the Adams Act, are not dependent on equivalent contributions from the States. The act extends the same supervision by the Secretary of Agriculture that has existed over previous appropriations for the stations. It therefore involves no new policy or administrative machinery, and no change on the part of the stations except an expansion of their activities.

The enactment of this law was a significant recognition of the value of the work of the stations to the Nation, all the more striking because of the definite policy of retrenchment to which the Federal Government was committed. It was not only a notable expression of appreciation of the past work of the stations and recognition of the need of expanding their activities, but it definitely provided for enlarging their activities in the newer and somewhat untried fields of agricultural economics, rural sociology, and home economics, which were properly demanding greater recognition and attention.

Appreciating the important departure the new act represents and the added responsibilities it placed upon the

¹ For history of the movement see Association of Land-Grant Colleges Proceedings, 1925, p. 63.

stations, a conference of representatives of the Association of Land-Grant Colleges and the Department of Agriculture was called at St. Louis, April 22, 1925, to consider policies and plans under it, and to bring into closer coordination and unity the investigations of the stations and the department. The Secretary of Agriculture, in an address before this conference, expressed the conviction that the act would mark a new epoch in the history of the experiment stations, and called attention to some of the conditions surrounding it. He referred to the fact that the act provides "for the more complete endowment and maintenance of agricultural experiment stations now established" and hence "attempts to build on top of what already exists. * * * Its primary purpose is to develop further investigation and experiment * * * of substantial character. It is a fact-finding, fact-interpreting measure.

"Tested methods of research should be applied to investigations which will yield the most useful results. Every effort should be made to avoid a type of superficial investigation which now has been outgrown. Problems of fundamental importance should be attacked by adequate methods and with full knowledge of other investigations in order to avoid wasteful duplication.

"In other words, what is most needed is thoroughly constructive work. The new fund is not for the exploitation of what is known or for speculation based on personal opinion or inadequate data, but it is for sound investigation in the best sense, calling for men and women with breadth and penetration of vision and of demonstrated ability in the research field."

The Secretary pointed out also that the Purnell Act recognizes in a substantial way the importance of finding solutions for the economic and social problems of the farm, and that for the first time it gives ample authority for carrying on investigation in home economics. He also stated that "the Purnell Act is not to relieve the States of their obligations. It is not designed to transfer these obligations to the Federal Government, but to enable the latter to join more liberally with the States in the maintenance of investigation at these institutions. * * * In advocating this latest legislation much emphasis was laid on what the States are now doing, and on the fact that it was not designed to relieve them but rather to stimulate and further extend their efforts. It is the confident

expectation, therefore, that the individual States will continue to bear their part."

With reference to the organization of the new work, the expectation was expressed that the projects and methods would show at the outset a definiteness of purpose and a clear conception of requirements, and owing to the limitations of the first year's appropriation it was advised that only a few new projects be started. Referring to the tendency to attempt too many diverse studies at a time, the Secretary said: "It will be well if we can say that the funds available through the first appropriation were not spread out over too many undertakings."

Special emphasis was laid on the importance of cooperation and coordination within the stations, between stations, and with the department and other agencies. On this point Secretary Jardine said:

"It is a reasonable expectation that the Purnell Act will lead to a considerable enlargement of the cooperative relations between stations and with the various bureaus of the department. This seems important at the present juncture. It is in line with the idea of organizing investigation around problems instead of around a single station department. Very many of the problems we now face are too large for individual States acting separately. They are regional or even national, and there is danger of viewing them too narrowly. An experiment station working single handed can rarely expect to reach conclusive and comprehensive results in such broad subjects. * * *

"There is already a large and constantly increasing amount of cooperation between different bureaus of the department and the stations in investigations of various kinds. It is believed that such cooperation will be even more desirable in the relatively new fields of agricultural economics, rural sociology, and home economics. Not only are the problems in these fields of wide range, but the available workers are relatively few, so that the utmost use should be made of them."

In line with these suggestions, the St. Louis conference adopted six major topics of national importance around which to organize cooperation, and provided special committees of specialists to formulate plans and procedure under each of them. These topics were:

- (1) Marketing and distribution of farm products.
- (2) The problem of surpluses.
- (3) Vitamin content of food.

(4) Rural home management studies.

(5) Rural social organization and agencies essential to a permanent and effective agriculture.

(6) A study of the factors which influence the quality and palatability of meat.

The special committees charged with the definition and plans of procedure under these topics presented their reports before the close of the fiscal year, outlining with considerable definiteness a number of projects which were considered advisable under these several topics. These were distributed through the Office of Experiment Stations by the joint committee on projects and correlation of research, representing the Association of Land-Grant Colleges and the Department of Agriculture. In calling attention to these national problems the committee expressed the opinion that they afford "an unusual opportunity of concentrating the attack on specific topics in a coordinated way which should lead to definite advance with the minimum waste of effort," and that "the ultimate success of this enterprise depends upon the full cooperation of all agencies, including the experiment stations and the Department of Agriculture." The committee therefore urged that the fullest consideration should be given to these plans, and that the response should be such as to give substantial encouragement for the various undertakings. As a result a large number of the stations indicated their purpose to cooperate in investigations on one or more of the topics.

In addition, sectional committees were organized at the St. Louis conference to arrange for cooperation in the study of special problems pertaining to their regions. The procedure thus set in motion for cooperative investigation and for approaching large problems on a coordinated plan was one of the significant features of the beginning under this new legislation.

ADMINISTRATION OF THE NEW ACT

In preparation for carrying out the part assigned to the Department of Agriculture in the supervision of the Purnell Act, the following circular was issued:

UNITED STATES DEPARTMENT OF
AGRICULTURE
OFFICE OF THE SECRETARY

Washington, D. C., May 20, 1925.

Subject: *Administration of the Purnell Act*

TO THE DIRECTORS OF THE AGRICULTURAL EXPERIMENT STATIONS:

The administration of the Purnell Act, with which the Department of Agriculture is charged, will be guided by the following general principles:

The underlying purpose of the act is "the more complete endowment and maintenance of agricultural experiment stations," a fact which recognizes the existence of an experiment station in each State as a going concern with an organization, administrative machinery, buildings, lands, and other basic facilities for research. In view of this and since the States are making substantial contributions toward the support of the stations, it would seem that general and overhead expenses such as apply to administration and upkeep, the care of buildings and grounds, maintenance of the farm and livestock, and similar ordinary expenses, might readily be cared for without drawing upon the new fund. It is the expectation, therefore, that the demand on the Purnell fund for general overhead expenses of the station will be reduced to the minimum.

The new act is designed to add to and strengthen the work of investigation; it directs that the funds appropriated in accordance with it "shall be applied only to paying the necessary expenses of conducting investigations or making experiments [in lines which are defined,] and for printing and disseminating the results of said researches." It is important, therefore, that the fund should represent definite pieces of investigation of substantial character, such as is called for in the present stage of agricultural inquiry.

With this idea in view, it will be expected that expenditures from the Purnell fund will be limited to those incurred primarily for specific investigations, with such charges for publication and for special buildings and lands as pertain directly thereto. The list need not be wholly restricted to new projects, but may include existing ones which it is desired to strengthen.

This will enable the Purnell fund to be administered on the same general plan as that followed with the Adams fund, namely, on the basis of a program of specific projects and a budget for expenditures, these to be submitted annually in advance for consideration and discussion in order that a good understanding may be reached. It is the more important because of the provision for expansion of investigation in several comparatively new fields, and the possibility of applying the fund to existing projects in other lines. All projects supported partly or wholly from the Purnell fund should therefore be submitted in outline in advance for examination and approval as to their suitability to the new appropriation.

Since an annual financial report on the Purnell fund is required under the act, it will not be possible to pool it with other funds, but a separate account upon it will be necessary, and the above plan will facilitate such an accounting. Where the support of projects is shared in by other funds, it should be possible to show quite definitely what the Purnell fund is being used for. As in the case of the Hatch and Adams funds, the account should be a current one, and should be supported by a set of vouchers readily available for examination on due notice. The classification will be on the same basis as for other funds, and the financial report will be rendered on the same blank with them.

The Office of Experiment Stations has been designated to represent this department in matters relating to the details of administration of this law, and will aid in the promotion of activities under this act in the same general way as it has heretofore in relation to the Hatch and Adams Acts. It will also be represented in negotiations for cooperation between the department and the experiment stations, and will maintain a file of such cooperative agreements.

Sincerely yours,

W. M. JARDINE
Secretary.

This circular was mailed in connection with a call by the Office of Experiment Stations for the program of operations under the act for the first year. In the latter it was explained that a separate statement regarding the program and budget for it was desired, that projects to be supported from the Purnell fund should be outlined as under

the Adams fund, with the assignment of funds, noting such projects as would be conducted cooperatively with other stations or with this department, and that it would simplify matters if the Purnell fund was not mixed more than was necessary with other funds in the support of projects.

With the prompt assent of all the States to the provisions of the Purnell Act, as called for by section 2 of the act, all of the States were certified to the Secretary of the Treasury as entitled to receive the benefits under it. Steps were immediately taken by the different stations to formulate at least tentative programs and budgets covering the first year's appropriation, and by the end of the year substantial progress had been made in agreeing upon acceptable lines of work. Subsequently detailed projects were submitted for approval, in accordance with the plan outlined in the above circular of the Secretary of Agriculture.

RESPONSE OF THE COLLEGES

The attitude of the agricultural colleges and experiment stations toward the Purnell Act was further expressed in the following items of policy later adopted by the station section and the executive body of the Association of Land-Grant Colleges at its 1925 convention:¹

(1) This act is supplementary to the two previous ones for experiment stations. It is to build upon what already has been provided. It is for a going concern, and it is not designed to relieve the States of their financial obligations. It is for new investigation or putting new force into work already underway.

(2) As it is supplementary and for increasing investigation, general overhead charges, except such as relate to the support of definite projects, are not considered warranted. The purpose the fund is serving will stand out more clearly if its admixture with other funds in the support of projects is held down to the minimum. To scatter it unduly and in small amounts over projects supported mainly from other funds will increase the task of administration and may suggest that it is being dissipated.

(3) The Purnell Act is designed to promote sound investigation in accordance with modern conceptions of that term and the present status of knowledge. Progress at this stage calls for clear-cut, concrete proposals. This implies analysis of complex problems and the study of individual features by the most adequate means that research has disclosed, with the constant aim of strengthening methods and making inquiry more penetrating.

(4) Only a relatively small field in the several branches of a station can be covered at a given time. Hence the plan of concentrating on a few topics in each field and making the work comprehensive, through, and conclusive is highly important. Do a few things well rather than many things indifferently.

(5) A systematic, well-rounded research program promises more at this stage than a fortuitous, disconnected set of projects. It enables a more adequate attack on the selected topics and a better related whole.

(6) The problem is the natural unit in the organization of research on many-sided subjects. A relationship will thus be established between the research in production and that in economics, sociology, and the home as a basis for "the establishment and maintenance of a permanent and efficient agricultural industry."

(7) The importance of cooperation and coordination within the stations, between stations, and with other agencies is recognized as now so definitely indicated as to make it a leading principle of administration. It is emphasized by the new fields of economics and rural life into which the stations are expanding. The breadth of many problems and their similarity in different sections favors joint effort in place of unrelated action. It is logical that the Department of Agriculture and the experiment stations should work in close union, and every effort should be directed to that end.

(8) Effective research requires trained workers, with a sound background in science quite as much as in their specialties. The need for investigators with vision, initiative, and keen perception is imperative at the present stage. The securing of such qualifications will mean the maintaining of a high standard of requirements and making positions sufficiently attractive to warrant the necessary preparation.

(9) The experiment station is one of the primary features of the college. Responsibility for discharging its functions does not cease with its administrative officers but is reflected on the parent institution. Sympathetic recognition and support of the essentials for research, the type of workers required, and the adjustment of their duties are fundamental in meeting just expectations under the new act.

(10) The administration of an experiment station has become a large and exacting matter. It has assumed an importance it has never had before. It calls for breadth of understanding and critical judgment in research, coupled with organizing ability and familiarity with the leading problems of agriculture. With the present growth in prospect, effective direction will call for time to study the whole situation—the needs of the State, the proposals submitted, the organization of joint efforts, and the maintenance of contacts with the progress of the work. Upon wise administration will depend in the first instance the effective use of the large appropriations for agricultural research.

This formulation of the attitude and policy which will govern the development of the stations at the present stage is strong evidence of the determination to make this new fund accomplish what its advocates had in mind. It gives a construction which will be helpful in guiding the department in its administration of the act.

FUNDS FOR STATION USE

The total amount of funds available to the experiment stations for the fiscal year ended June 30, 1925, was \$10,581,975.87, or an increase in station resources over the preceding year of \$342,901.31. Of the total income for the year \$1,440,000 was derived from the Federal appropriations under the Hatch and Adams Acts and \$238,280 from specific appropriations for the stations in Alaska and the insular possessions. The main support of the stations came from State appropriations, which amounted to \$5,827,871.88, and the remainder—\$3,075,823.99—of the total revenues represents the bal-

¹Association of Land-Grant Colleges Proceedings, 1925, pp. 182, 388.

ance carried over from the previous year and income from fees, sales, and miscellaneous sources. The total and summarized statement of the receipts and expenditures is given on page 154.

STATE CONTRIBUTIONS

For a considerable number of years there has been steady increase in the amount of money provided by the States for the support of the experiment stations. This, together with the provision of needed buildings and land and other facilities for carrying on investigation, has better prepared the stations for a broader field of operations. The volume of these State funds shows the

background upon which the new Pur-
nell fund was projected and the liberal
manner in which the States are supple-
menting the Federal appropriations.

In the fiscal year 1925 the stations in the 48 States had for their use a total of \$10,343,695. This was an increase of nearly \$310,000 as compared with the preceding fiscal year. Of this amount \$8,903,695 was from State sources. Direct State appropriations aggregated \$5,827,871, balances brought forward from the preceding year amounted to \$1,041,867, and the total from sales was \$1,390,480. The remainder was derived from fees and miscellaneous sources. Totals by States are shown in Table 1:

TABLE 1.—*Income of the agricultural experiment stations from within the States for the year ended June 30, 1925*

States	State appro- priations	Balances	Fees	Sales	Miscel- laneous	Total
Alabama	\$34,500.00	\$16,048.56		\$16,329.17		\$66,877.73
Arizona	96,394.84	936.21		3,337.65		100,668.70
Arkansas	74,665.45			17,102.22	\$1,400.00	93,167.67
California	507,937.93	34,553.67	\$8,699.76	70,664.97	14,004.88	635,861.21
Colorado	122,132.53	33,639.28		24,317.24		180,089.05
Connecticut State	73,870.74	6,169.99	14,500.00		8,882.57	103,423.30
Connecticut Storrs	32,000.00	7,773.34			16,986.58	56,759.92
Delaware	17,500.00	2,301.29		14,407.00		34,208.29
Florida	87,500.00	24,104.90		9,989.91		121,594.81
Georgia	8,000.00	2,549.26		10,977.19		21,526.45
Idaho	26,794.59	460.02				27,254.61
Illinois	395,444.62	31,723.22		61,704.38		488,872.22
Indiana	226,160.07	114,280.44	145,070.36	100,217.64	22,022.44	607,750.95
Iowa	265,000.00	26,065.03		53,843.75		344,908.78
Kansas	100,400.00	18,645.06		78,165.80		197,210.86
Kentucky	113,000.00	31,190.86	99,432.44	42,911.24	5,000.00	291,534.54
Louisiana	40,000.00	8,624.26		30,626.05	17,075.95	98,112.44
Maine	25,000.00			11,816.40	15,528.96	52,345.36
Maryland	80,865.38				17,610.56	5,341.99
Massachusetts	134,193.17			39,977.05	14,392.81	103,817.93
Michigan	284,835.47				132.93	188,695.96
Minnesota	323,628.91					284,835.47
Mississippi	126,869.76	54,353.00		80,209.99		403,838.90
Missouri	71,148.88	43,823.00	28,145.46	12,330.58		193,553.34
Montana	110,727.53	4,096.19		37,665.89		180,783.23
Nebraska	128,519.10	8,151.17		19,285.02	282.74	134,391.48
Nevada	1,557.20	1,154.99		51,771.82		188,442.09
New Hampshire	7,000.00	3,472.96		1,159.52		3,871.71
New Jersey	129,230.73		49,219.11	29,020.71		27,526.45
New Mexico	7,500.00	21,811.26		8,000.00		37,311.26
New York Cornell	240,314.27			24,725.29		265,039.56
New York State	254,740.00			8,194.00		262,934.00
North Carolina	155,945.00	2,144.86		43,444.39	844.86	202,379.11
North Dakota		178,366.61		75,529.51	11,000.00	264,896.12
Ohio	405,675.00	348,073.20		50,041.19	2,375.05	706,164.44
Oklahoma	12,500.00	998.48		14,426.94		27,925.42
Oregon	104,500.00	52,454.98			27,932.75	184,887.73
Pennsylvania	60,408.80			10,906.90	11,236.24	82,551.94
Rhode Island	4,516.82	161.45		5,469.22		10,147.49
South Carolina	72,545.79	2,083.33		41,452.04		116,081.16
South Dakota	35,420.00	7,643.50		17,325.26	1,778.74	62,167.50
Tennessee	33,620.61			17,811.27		51,431.88
Texas	217,000.00	32,935.23		82,772.56	52,903.84	385,611.63
Utah	46,891.71	2,225.76		18,061.31	259.85	67,438.63
Vermont	12,560.78	65.38		1,000.41		13,626.57
Virginia	70,156.25	8,222.56		9,072.10	616.40	88,067.31
Washington	101,955.82			49,727.36		151,683.18
West Virginia	85,000.00	8,769.48		38,653.22		132,422.70
Wisconsin	249,244.13			70,773.61	16,337.20	336,354.94
Wyoming	12,500.00	1,794.93		884.37		15,179.30
Total	5,827,871.88	1,041,867.71	427,486.63	1,390,480.48	215,989.17	8,903,695.87
Federal funds						1,440,000.00
Total						10,343,695.87

As in the preceding year, all the stations received State aid in 1925, but in several instances the amount of State support was quite limited. The State appropriations of 12 stations remained without change, while those of 24 stations showed an increase and those of 14 a decrease. Only 4 stations—California, Ohio, Illinois, and Minnesota—mentioned in the order of decreasing amounts received, reported State appropriations amounting to more than \$300,000. Seven stations receiving between \$217,000 and \$285,000 were Michigan, Iowa, New York State, Wisconsin, New York Cornell, Indiana, and Texas. The State appropriations of the following 11 stations ranged between \$100,000 and \$156,000—North Carolina, Massachusetts, New Jersey, Nebraska, Mississippi, Colorado, Kentucky, Montana, Oregon, Washington, and Kansas. Ten stations receiving between \$60,000 and \$97,000 were Arizona, Florida, West Virginia, Maryland, Arkansas, Connecticut State, South Carolina, Missouri, Virginia, and Pennsylvania. Eight stations—Utah, Louisiana, South Dakota, Alabama, Tennessee, Connecticut Storrs, Idaho, and Maine—received from \$25,000 to \$47,000, and 4 stations—Delaware, Vermont, Oklahoma, and Wyoming—received from \$12,500 to \$17,500. Five stations—Georgia, New Mexico, New Hampshire, Rhode Island, and Nevada—received less than \$10,000 each. The North Dakota station reported no appropriation for this, the last year of the biennium for which State appropriations were made, but reported a balance of \$178,366.61 carried over from the previous year.

As in previous years, the purposes for which the Federal funds were expended were ascertained for each station and the progress of the work as a whole, whether supported from these or other funds, was noted.

PERSONNEL OF THE STATIONS

There were 2,415 persons in the regular employ of the stations (not including laborers) during the year. This was a slight increase over the previous year. Of the total number of workers, over half, 1,265, took some part in the teaching in the colleges, their salaries being proportionately divided, and 347 assisted in the extension work. Of the total personnel, approximately half were independent workers or project leaders, the others being of the grade of assistants.

The station personnel has undergone a marked change, due to the character of the work and the demands upon it. In the earlier years, when the work was more elementary, the need for funds and for suitable facilities was to a large extent the limiting factor. Workers were adapted from the teaching force, and persons of limited experience or range of training could render acceptable service for the time. But with the change in the status of research the requirements for persons of sound training and experience have been increasingly felt. This has resulted in raising the standards for new recruits in most lines, and has stimulated large numbers of prospective station workers, or those already so engaged, to prepare themselves by advanced study and contacts with the methods of inquiry. While in some branches of the work this more severe preparation has lagged behind somewhat, the improvement in most branches has been very marked, and with the expansion now provided the demand for broadly trained investigators will be considerably increased.

The Purnell Act definitely broadens the field of research in the stations, and it was in these new fields of investigation that interest at first largely centered and in which there was the greatest immediate activity in the formulation of projects. In some of these lines the research field is only partially organized. One of the preliminary tasks has been to get better acquainted with the field, the points on which more detailed and fundamental information is needed, and the means of approaching the complex problems involved.

This has called for leaders, with vision and initiative, of which the number at the outset was not wholly adequate. The shortage has delayed some of the stations in embarking on these lines for the time being. This condition and the opportunity now open already are stimulating persons to prepare themselves for it and encouraging educational institutions to give special attention to the demand. In these newer fields, as well as in the better established ones, the measure of the research will be determined first of all by the corps of workers. They occupy the first place—funds and facilities are merely means of fostering their activities.

The campaign for new workers has naturally increased the competition among institutions to some extent and may result in considerable shifting, especially if opportunities are not adjusted. The situation has also made it

necessary to offer more liberal salaries in special cases, but the average for the most part is still not large.

A survey of the situation in the spring of 1925 showed that for persons ranked as department heads, leaders of separate lines, and independent workers, the salary ranges all the way from \$2,400 to \$6,000. Both of these extremes are, of course, exceptional. In three States the range was from \$2,400 to \$2,750, while for the larger proportion of the States it was from \$3,000 to \$4,500. In seven States the maximum salary paid workers of this rank was \$3,500, and in half it did not exceed about \$4,000, while in eight others it was within \$4,500. In only nine States was the maximum for department heads or independent workers \$5,000 or over. On the whole, it can not be claimed that the experiment stations are extravagant in the matter of salaries, and the probability is that in the more advanced positions and those calling for special training the amount will have to be increased.

CHANGES IN PERSONNEL

Although changes in personnel were numerous the turnover was less than for the previous year, indicating an encouraging degree of stability of the station staffs. The major changes during the year were as follows:

Changes in directorships.—L. E. Call was appointed director of the Kansas station and dean of the division of agriculture, succeeding F. D. Farrell, who had been elected president of the college upon the appointment of W. M. Jardine as Secretary of Agriculture. H. J. Patterson, director of the Maryland station, was made also dean of the college of agriculture. B. W. Kilgore, director of the North Carolina station, resigned, and was succeeded by R. Y. Winters, plant breeder of the station. H. L. Russell, director of the Wisconsin station, was granted leave of absence for study of the dairy industry of New Zealand, F. B. Morrison acting as director in his absence.

Other changes.—W. L. Blain was appointed associate plant pathologist at the Alabama station.

F. J. Crider, horticulturist at the Arizona station, resigned, and A. R. Kinison was made acting head of the horticultural work and citriculturist. P. S. Burgess was appointed chemist at this station.

C. B. Hutchison, director of the Davis branch of the California College of Agriculture, resigned to take up work with the International Education Board. W. H. Boynton, formerly of

the Philippine Bureau of Agriculture, was appointed veterinarian for the special study of hog cholera vaccines. Appointments as associates in the station included I. J. Condit in subtropical horticulture, and F. Silvestre as entomological explorer, with headquarters at Hongkong, China. Jacob Traum, associate in veterinary science, was granted leave of absence for the study of foot-and-mouth disease in Europe.

L. W. Durrell was appointed botanist at the Colorado station, and J. C. Ward soil chemist at the Arkansas Valley substation.

P. J. Anderson, of the Connecticut State station, was placed in charge of the tobacco substation at Windsor.

P. B. Meyers succeeded L. W. Tarr as chemist at the Delaware station. A. E. Tomhave was transferred to the station as animal husbandman, vice T. A. Baker, who was transferred wholly to teaching. E. M. K. Lamkey, plant physiologist, resigned.

J. F. Cooper was appointed agricultural editor at the Florida station vice Ralph Stoutamire, resigned.

At the Idaho station, R. B. Gray, agricultural engineer, resigned and was succeeded by his associate, M. R. Lewis.

At the Illinois station, W. E. Carroll, of Utah, was appointed chief in swine husbandry, assuming his duties February 1. I. B. Boughton, assistant chief in animal pathology, resigned in April to take the directorship of the animal disease control work in Haiti. Robert Graham, who had been on a leave of absence in Haiti, returned to his duties as chief in animal pathology and hygiene at the station.

E. G. Proulx, who was connected with the chemical department of the Indiana station for some 15 years, died March 31, 1925.

At the Iowa station, E. S. Haber, assistant professor of horticulture in the college, was appointed assistant chief in truck crops vice W. C. Calvert, resigned. Wallace Park returned to his former position of assistant chief in apiculture, after an absence of two years at the University of Illinois.

At the Kansas station, R. I. Throckmorton succeeded Director Call as head of the department of agronomy. G. E. Johnson was appointed mammalogist and A. T. Perkins, research chemist.

P. H. Senn was appointed microscopist at the Kentucky station, and S. J. Lowry was made superintendent of the newly established substation at Princeton.

F. H. Leuschner was appointed associate poultry husbandman at the Maryland station.

C. H. Werkman, of Iowa, succeeded Arao Itano as research professor of microbiology at the Massachusetts station.

F. A. Spragg, research associate in crop breeding at the Michigan station, was killed in an automobile accident, August 11, 1924; and L. H. Cooledge, research associate in bacteriology, died May 12, 1925. C. G. Card was made acting head of the poultry department upon the resignation of E. C. Foreman. G. H. Coons, research associate in plant pathology, was granted leave of absence to conduct sugar investigations in the Office of Sugar Plant Investigations of this department. H. J. Stafseth, associate in bacteriology and specialist in diseases of poultry, was appointed exchange professor under the American-Hungarian Foundation, to spend a year in study at the University of Budapest. J. F. Cox, head of the farm crops department, was granted a four-months' leave for the purpose of serving the Federated Seed Service at Chicago.

At the Minnesota station, W. B. Combs was appointed dairy husbandman, and A. H. Johnson, biochemist, to carry on C. H. Bailey's work during his year's leave of absence.

C. J. Goodell was made associate animal husbandman at the Mississippi station, being transferred from the department of agricultural economics to this position. E. P. Brintnall, associate dairy husbandman, and H. D. Barker, associate plant pathologist, resigned.

H. R. Kraybill, chemist at the New Hampshire station, resigned and was succeeded by T. D. Phillips, of Ohio State University.

At the New Jersey stations, C. C. Hamilton succeeded Alvah Peterson as associate entomologist. W. C. Thompson, chief of the department of poultry husbandry, was given two years' leave of absence, beginning November 1, 1924, to serve as temporary director of the National Poultry Institute of England, established for advanced instruction and research.

R. F. Crawford succeeded R. L. Middlebrook as head of the department of biology at the New Mexico station. J. L. Lantow resumed his duties as animal husbandman July 1, 1924, after a year's leave of absence spent at the University of Illinois.

Appointments at the New York Cornell station included P. F. Sharp in dairy chemistry, E. F. Phillips in apiculture, H. E. Thomas in plant pathology, I. C. Hall in bacteriology, and J. N. Spaeth in forestry. J. R. Schramm, botanist, resigned to become editor-in-chief of the new International Biological Abstracts. R. A. Emerson, head of the department

of plant breeding, was made also dean of the graduate school. W. M. Wilson, head of the department of meteorology, and T. J. McInerney, in dairy husbandry, were granted leaves of absence.

At the New York State station, D. C. Carpenter was appointed associate in research in chemistry.

H. L. Walster, agronomist at the North Dakota station, was made also dean of the school of agriculture.

A. Bonazzi, in charge of soil biological investigations at the Ohio station, resigned to become director of the Chappara sugar cane experiment station at San Manuel, Cuba. M. A. Bachtell was appointed associate in farm management, to have charge of the three district and nine county farms. A. G. Newhall was appointed associate in plant pathology. Leave of absence for graduate work was granted R. C. Thomas, associate in plant pathology.

P. L. Menaul, chemist of the Oklahoma station, resigned and was succeeded by V. G. Heller, professor of chemistry in the college.

At the Pennsylvania station, C. D. Dahle was appointed associate in dairy manufactures. A division for storage research was established in the department of horticulture and L. M. Marble was placed in charge. F. D. Kern, head of the department of botany, was given a year's leave of absence, part of which time was to be spent as acting dean of the Porto Rico College of Agriculture at Mayaguez.

B. E. Gilbert was appointed chemist at the Rhode Island Station.

F. H. Lathrop was appointed entomologist at the South Carolina station to fill the vacancy caused by the resignation of A. F. Conradi. C. P. Blackwell, the station agronomist, resigned.

At the Texas station, Frank Grayson succeeded J. J. Hunt as wool and mohair grader. E. J. Wilson was made superintendent of the newly established substation in Wichita County. Upon the separation of dairy, swine, and poultry husbandry from the general lines of animal industry, G. R. Warren became chief of the divisions of dairy and swine husbandry, and R. M. Sherwood was made chief of the division of poultry husbandry. H. J. Reinhard, entomologist, who had been on leave of absence, resumed his duties May 1, 1925.

G. R. Hill, jr., botanist and plant pathologist at the Utah station, and dean of agriculture in the college, resigned, as did Gustav Wilster, associate in dairy manufactures. G. Q. Bate-man was placed in charge of the Cronquist experimental dairy farm, and

J. W. Carlson was made superintendent of the experimental farm at Fort Duchesne, established for alfalfa seed work.

Ezra Brainerd, formerly president of Middlebury College and for several years associated with the Vermont station in botanical work on Rubus and Viola, died December 8, 1924.

At the Virginia station, C. E. Seitz, who resigned in the early spring, resumed his duties as agricultural engineer. R. A. Runnells was appointed associate animal pathologist. G. S. Ralston, field horticulturist, resigned. F. P. McWhorter was appointed associate horticulturist at the Truck station, Norfolk, vice R. J. Davis, resigned.

M. A. McCall, superintendent of the Lind, Wash., substation, resigned to come to the Bureau of Plant Industry of this department.

C. A. Lueder, veterinarian at the West Virginia station, resigned.

L. J. Cole, head of the department of genetics at the Wisconsin station, resumed his duties September 1, 1924, after a year's absence spent with the United States Department of Agriculture. Theodore Macklin was granted leave of absence to be spent in a study of the dairy industry of New Zealand.

ADDITIONS TO BUILDINGS AND EQUIPMENT

Substantial additions were made to the buildings and equipment of the stations during the year, largely, however, in the nature of minor improvements and special equipment for investigation. The total value of such additions was \$1,475,201 as compared with \$2,013,785 the previous year, classified as follows: Buildings, \$782,789; farm implements, \$136,887; livestock, \$129,-313; apparatus, \$98,956; library, \$35,-379; miscellaneous, \$291,876.

Some of the major features of improvements in buildings and equipment were as follows:

A State appropriation of \$300,000 was made in Arkansas for the construction of a new building for the college of agriculture at the State University of Arkansas in which the station will share, and a grant of \$10,000 was made for the establishment and maintenance of three substations for cotton, rice, and truck crops, respectively. Office facilities were provided at the station farm which were expected to be of material convenience in the experimental work.

The construction of a range of 10 greenhouses, each 30 by 80 feet, was begun at the California station. These houses were to be divided among 11 de-

partments of the college of agriculture, with the larger proportion of the space allotted to pomology, plant nutrition, landscape gardening, and genetics. The funds for this purpose were supplied in part by the State and in part by private subscription. The construction of a stationary spray plant was begun at the university farm, the orchards being piped with mains connected with the stationary pumping plant.

The Florida Legislature provided for the erection of the first unit of a new agricultural building at the University of Florida to cost \$125,000. This was to be used in part for station purposes.

A science building to be used partly for station purposes was completed at the University of Idaho at a cost of \$400,000.

The installation at the Illinois station of a respiration apparatus sufficiently large to accommodate cattle and small horses, for the use of the division of animal nutrition, was undertaken. Metabolism crates for sheep and swine and a respiration apparatus for poultry were also provided.

A new experimental greenhouse costing \$12,000 was completed at the Indiana station for use in experimental work in soils and crops and horticulture. The addition of this equipment also makes possible an expansion of the experimental work in pathology, physiology, and entomology. A house and laboratory costing \$6,000 was completed for nutrition investigations and the breeding and care of small animals for this purpose. A hog barn was constructed at the livestock experimental farm at a cost of \$5,500.

Contracts were let for a new home economics building at Iowa State College to cost about \$600,000. This will afford better facilities for both college and station work. A new livestock judging pavilion 100 by 56 feet and costing \$20,000 was under construction.

The biennial appropriations for the Kansas college and station carried among other items \$10,000 for a sheep barn, \$10,000 for new greenhouses, and \$22,000 for additional land, partly for experimental purposes.

Approximately 400 acres of land near Princeton in Caldwell County was donated by citizens of the county for the use of the Western Kentucky substation, authorized by the State legislature in 1924, with an annual appropriation of \$10,000. The same legislature also appropriated \$25,000 annually for the establishment and maintenance of the Robinson substation at Quicksand in eastern Kentucky. This substation comprises about 15,000 acres of land and is to

give special attention to forestry investigations.

A sugar mill for experimental and instruction purposes was erected at the Louisiana station at a cost of \$58,000.

A new \$125,000 dairy and refrigerating plant was put into operation at the Maryland college and station. This is mainly for college and commercial purposes, but also to be used for experimental work.

A new wing was added to the home economics building of the University of Missouri, which it was expected would not only provide additional student facilities but furnish more adequate facilities for research in foods, nutrition, textiles, clothing, and home management.

The agronomy farm of the Nebraska station was enlarged by 175 acres, and a contract was let for a small cottage at the Valentine substation. Plans were made for a new dairy barn, sheds, and yards, as well as an open shed and beef cattle barn at the outlying farm.

Plans were made for a new plant industry building at the college of agriculture of Cornell University, which was expected to cost nearly \$500,000.

The erection of an animal husbandry building with a State appropriation of \$225,000, to be used partly for station purposes, was begun at North Carolina State College.

The Ohio station completed and occupied an agronomy building, to be known as Thorne Hall, with a State appropriation of \$90,000.

The Utah Legislature appropriated funds for establishing two new experimental farms, one in San Juan County and the other in Uintah County. These farms were provided for the purpose of carrying on experimental work in the growing of alfalfa seed.

An appropriation was made by the State legislature for completion of the dairy manufactures building at the Washington station. Appropriation was also made for replacing the beef cattle barn.

STATION PROJECTS

The wide scope and variety of the work of the experiment stations is brought out by the classified list of projects active during 1924-25, which was prepared and distributed by the office during the year. This list shows 5,538 such projects for the State experiment stations and 150 for the experiment stations maintained by the department in Alaska and the insular possessions, making a total of 5,688, as compared with 5,420 the previous year. Of these,

however, 54 are purely administrative and regulatory. Hence, the number of projects devoted strictly to research and experimentation was 5,634, or an average of more than 100 to the station.

The subject distribution of the projects differed little from that of the previous year. Field crops led with 1,817 projects, followed by horticulture 952 projects, animal production (including dairy cattle 191 and poultry 205) 926, plant pathology 482, entomology 472, soils 343, agricultural economics 235, fertilizers 213, veterinary medicine 203, agricultural engineering 189, botany 144, genetics 126, dairy products 106, forestry 100, foods and human nutrition 54, and various others.

There were increases during the year of 95 projects under field crops, 50 under entomology, 49 under agricultural engineering, 43 under soils, 33 under horticulture, 32 under plant pathology, 32 under poultry, 26 under economics, 25 under forestry, and small increases under various other subjects.

Force of circumstances owing to demand for their services has led many of the experiment stations in the past to spread their funds and their resources over a larger number of inquiries than can be prosecuted intensively and energetically. The nature of the problems at the present time for the most part calls for intensive study. The requirements are not met by empirical experiments which only give comparisons applicable for the time and the conditions, and are not expressed in terms showing permanent relationships.

The real advances in agricultural practice and teaching have come from the application of knowledge and understanding, gained through close study and use of all that has been discovered by others, both as to facts and the light they throw on the real nature of the problem. Research attempts to build upon this foundation of information by making new contributions. It is needless to conduct more experiments unless they disclose something new or strengthen beliefs which need further confirmation.

Such procedure which aims at disclosing underlying facts and principles has become increasingly the objective in the investigations of the experiment stations. It recognizes the broad general background which has already been provided, and the fact that agricultural investigation, like all research, is a forward-looking effort, progressing on the basis of its own and related inquiries. Naturally it is a far more exacting type

of activity than the making of conventional experiments or following the routine of a long series of established trials. It calls, therefore, for concentration, the centering of effort on a few subjects, with close application to them.

With an undue increase in number of projects the tendency is for workers to scatter their efforts over too wide a field, not to go deep enough to get the basic facts, and not to put enough of themselves into the individual experiments to be constructive. Diffuseness is one of the evils that still needs to be guarded against.

The situation emphasizes the importance of the steps already taken to evaluate the projects under way and the promise they hold out to sift them critically and set high standards of performance to which they must conform. Unless they can justify themselves by their method and the evidence or prospect of progress, they are not in harmony with the present-day program of agricultural research. This is in accordance with the suggestion of the Secretary of Agriculture at the St. Louis conference, who said:

"The time also is opportune for taking stock of our present work, both in the Department of Agriculture and in the stations. Useless projects should be weeded out. Wasteful duplication should be stopped. The work in some lines of research may be broadened perhaps or better coordinated with other work. The purely scientific work can and should be better correlated with the economic work. Close scrutiny of its entire range of work by each of the stations, and closer cooperative relations between stations will be of far more importance to the future development of agriculture than any strict supervision which the Department of Agriculture might exercise."

WORK IN RURAL ECONOMICS AND SOCIOLOGY AND HOME ECONOMICS

A critical study of what might profitably be done to increase and strengthen investigation in rural economics and sociology and home economics as provided by the Purnell Act, has revealed a considerable diversity of opinion and practice in this respect, but strongly emphasizes the importance of a constructive purpose and definite objectives in all such work, as in other fields of research. There appears to be nothing to justify the setting up of standards of work in these fields essentially different from those accepted for other lines of investigation. Because the subjects have been less studied the

work may necessarily be somewhat elementary in certain respects at the outset, but the aim will undoubtedly be to make the investigation of them purposeful, thorough, and progressive.

THE INSULAR EXPERIMENT STATIONS

There was substantial progress during the year in the work of the agricultural experiment stations maintained by the Department of Agriculture in Alaska, Hawaii, Porto Rico, Guam, and the Virgin islands, the work and expenditures of which are supervised by Walter H. Evans, chief of insular stations.

These stations were established and are maintained by the Federal Government primarily for the purpose of developing the agricultural possibilities of their respective territories in accordance with local needs and environmental conditions.

The experimental work in Alaska was carried on as in previous years at Sitka (headquarters) and Kodiak on the coast, and at Rampart, Fairbanks, and Matanuska in the interior. The work is done under widely varying conditions and is designed to establish such types of agricultural production as will supplement and aid in the development of other industries.

The experiment stations in Hawaii and Porto Rico are attempting to find profitable ways of diversifying the agriculture of those territories now centered largely on cane sugar production.

In Guam an effort is being made to improve the primitive methods of farming and to restore agriculture to its former important position.

In the Virgin Islands the effort is to show how diversified agriculture may improve the disturbed economic conditions and furnish profitable employment for many who formerly were otherwise employed.

The results of the work of the insular stations are published in detail in their reports, bulletins, and circulars.

The appropriations for the stations for the fiscal year ended June 30, 1925, were as follows: Alaska \$69,500, Hawaii \$53,000, Porto Rico \$50,000, Guam \$15,000 and Virgin Islands \$22,500. In addition, \$23,280 was appropriated to adjust the salaries of all the stations to make them as nearly as possible comparable with those in Washington, D. C., and a deficiency act of December 4, 1924, appropriated \$8,000 for the control of the coconut scale in Guam, which had become a serious menace in the island.

CHANNELS OF PUBLICATION

The results of station work are published mainly through their regular series of reports, bulletins, and circulars, but to an increasing extent other channels of publication are being used and a wider and more varied dissemination of information secured.

The total number of regular publications issued by the stations during the year was 1,059, aggregating 26,537 pages and distributed to 853,732 addresses on mailing lists, in addition to those sent on special request. A classified list of these publications will be found on page 139.

Thirty articles prepared wholly by the experiment stations and nine others in which they collaborated were published in the *Journal of Agricultural Research*. Twenty-four stations were represented by one or more of such contributions. In addition, the stations contributed 1,305 articles relating to or based on their work to 290 other scientific and technical journals.

SOME RESULTS OF RECENT STATION WORK

The following classified review calls attention briefly to a few representative examples of contributions on a limited number of topics in the various fields of station work during the year covered by this report. It does not attempt a complete summary of all important current work of each station.

SOILS AND FERTILIZERS

Fully one-tenth of the recorded station projects deal with soils and fertilizers. The work covers a wide range and deals with many subjects of fundamental importance, especially with reference to crop and soil adaptation, use of fertilizers and other means of securing optimum conditions for crop production and maintaining soil fertility, and improvement of methods of tillage and soil management. The more generalized surveys and experiments are being supplemented to an increasing extent by specific studies of soil properties in their relation to fertility, productiveness, tillage, and crop adaptation.

Volume weight of soil.—Determinations of the volume weight of three types of soil by the Illinois station indicated that the present arbitrary values of 2,000,000 pounds for the surface 6 $\frac{2}{3}$ inches, 4,000,000 pounds for the subsurface 6 $\frac{2}{3}$ to 20 inches, and 6,000,000 pounds for the subsoil 20 to 40 inches are inaccurate in most cases. The

average of three types of soil tested showed variations from 1,750,000 to 2,000,000 pounds for the surface 6 $\frac{2}{3}$ inches, from 3,400,000 to 4,350,000 pounds for the next layer, and from 5,750,000 to 6,750,000 pounds for the 20 to 40 inch stratum.

Soil moisture and solution.—The soluble salt content of the soil was found by the Minnesota station to be correlated with the amount of water required for the production of dry matter in the plant. High osmotic concentration of the soil solution favored low water requirement in *Atriplex* and wheat.

The suction force of soils measured with the aid of a mercury manometer attached to a porous clay candle filled with water and inserted in the soil has been proposed by the New Jersey stations as a measure of capillary and molecular forces, with especial reference to the influence of soil colloids, the force of water absorption by roots of plants, and in obtaining soil solutions.

Soil moisture.—The California station has demonstrated the existence of two definite soil moisture capacities representing the minimum and maximum amounts of moisture retained by the soil when the water is applied at the surface and is free to move downward through the soil mass. This has an important bearing on cultural practice under irrigation, as well as under humid region conditions, particularly on the functioning of mulches and other means of moisture conservation.

Effect of mulches.—Soil mulch inhibited absorption of moisture in case of light rains by increasing evaporation, in investigations reported by the Washington station. When conditions especially favored evaporation, there was greater loss from mulched soils. Mulching, however, prevented loss of moisture already in the soil. Conditions may accentuate one or the other or nullify both.

Permeability.—All sodium compounds, except the acid salts of strong acids, were found by the New Mexico station to have a depressing effect on the permeability of soils, while the similar compounds of potash had comparatively little effect. Sodium carbonate had the most depressing effect. The salts of divalent metals did not depress the permeability. Some substances, such as aluminum sulphate, acid phosphate, manure, and salts with acid reaction, were found to improve the permeability. Ammonium sulphate was without immediate effect on permeability, sodium nitrate depressed it considerably, while acid phosphate improved it. Aluminum sulphate proved

not to be toxic in the soils studied and gives promise of becoming a satisfactory remedy for the treatment of impermeable areas which develop in irrigated lands. The Missouri station found that with liberal applications of rather insoluble salts, like calcium sulphate and carbonate, clay would remain flocculated for several years under ordinary conditions of leaching.

Colloids—Chemical analyses of colloidal clays derived from different kinds of soils, reported by the Missouri station, showed that such colloids are rather uniform in composition. Although the evidence obtained from a study of both soil colloids and synthetic mixtures of colloidal Al_2O_3 , Fe_2O_3 , and SiO_2 was not conclusive, "it would seem to indicate that many colloidal clays at least are composed largely of complex aluminosilicates rather than a mixture of the separate colloidal oxides. The chemical reactions of these alumino-silicates seem to follow the ordinary laws of chemical valence with the special condition that the reaction is restricted to the surface of the particles." The colloidal clays appear to act as weak acids.

Minor soil constituents.—Copper, manganese, and zinc, according to the Kentucky station, commonly occur in small amounts in fertile soils and in the plants grown on them and appear to play an essential part in plant growth and perhaps also in animal nutrition.

Aluminum toxicity.—The Rhode Island station found that the growth of more sensitive seedlings, such as beets and lettuce, was much depressed with 3.4 parts per million of alumina in the nutritive solution, whereas four times this concentration had only a slight effect on the growth of such plants as oats, corn, and cabbage, which are highly resistant to acid soil conditions in the field. The Hawaiian Sugar Planters' Station has shown that certain acid soils of low productive capacity for sugar cane contained soluble aluminum and iron and that the infertile condition may be attributed to aluminum toxicity, which is in a measure corrected by applications of potash salts and soluble phosphates.

Magnesium toxicity.—Hydrated silica was found by the Tennessee station to decrease the solubility of magnesium compounds in the soil and reduce their toxicity to tobacco.

Soil acidity.—The Rhode Island station observed that soil acidity conditions change with the crop grown. Alkaline crops, such as mangels and buckwheat, remove more alkaline than acid constituents and therefore tend to make a soil more acid, whereas carrots and millets remove more acid than alkaline

constituents, leaving the soil less acid. The Iowa station found that acid phosphate lowered the hydrogen-ion concentration of the soil more than did ammonium sulphate and potassium chloride and that the acidity persisted for some time, especially in poorly buffered soil. In other soils the acidity quickly disappeared.

Buffer action.—The Delaware station found that different soil types of the State varied more in their "buffer" qualities than they did in pH values. Some of the soils were so poorly buffered that they were easily thrown out of proper balances for optimum crop conditions, while other soils were so highly buffered that but little change was made in their pH values by heavy additions of either acid or alkali. The buffer action of all soils tested decreased as the temperature increased. The Michigan station showed that the buffer action of acid soils toward acids and bases closely parallels the adsorption phenomena displayed by pure activated sugar charcoal, indicating that, in part at least, soil acidity is due to adsorption effects.

Replaceable bases.—When the replaceable base in heavy clay soils was potassium, the water-holding power of the soil was found by the Utah station to be greatly reduced, indicating that the very fine capillaries were reduced in size and number. Soils saturated with calcium showed the highest water-holding power, those saturated with sodium being intermediate in this respect. The conditions were reversed, however, with a high water content, in which case sodium-saturated soils held the largest amount of water and calcium-saturated the least.

From a beneficial standpoint replaceable calcium appeared to be the most important single element in soils, according to experiments reported by the Oregon station. From the standpoint of soil troubles, however, and especially under alkali conditions, replaceable sodium appeared to be the most important element. No relation between physical character of the soil experimented with and the amount of replaceable base was observed.

Alkali soils.—According to the California station alkali soils in general may be classed in three groups: (1) Those which contain high concentrations of soluble sodium salts and are low in soluble calcium salts, which soils have excessive amounts of replaceable sodium and require special treatment with gypsum, sulphur, or some similar material for their reclamation; (2) soils with high soluble sodium salts and considerable soluble calcium, which

contain an intermediate amount of replaceable sodium and may or may not require special treatment, depending upon their organic and calcium carbonate content; and (3) soils with high water-soluble calcium salts, which soils are merely in need of leaching and drainage. In the reclamation of all of these soils the drainage question is of primary importance. The station found that it is possible by laboratory methods, to determine the nature of the treatment required by a given alkali soil.

Effective correction of black alkali, sodium carbonate, by use of gypsum was reported by the Arizona station. The application of gypsum not only improved the drainage but effected an important saving of the plant food of the soil. The gypsum did not penetrate very deeply into the soil, but the crop results indicated that if an excess of gypsum is kept in the surface foot of the soil a considerable concentration of black alkali will be tolerated in the subsoil.

Organic matter.—The Washington station concludes from its investigations that in any system of agriculture (except where acid soils are brought under irrigation) it is impossible to maintain the soil organic matter content at the point at which it was found in the virgin state. There is a definite relationship between the organic nitrogen and carbon in the soil, and this relationship has a tendency to maintain itself under natural conditions, with the result that the effective organic matter in the soil can not be increased or even maintained unless the nitrogen is also increased or maintained. When organic matter is lost from the soil as a result of decomposition the carbon is lost more rapidly than the nitrogen and the remaining organic matter becomes more and more resistant to decay as its nitrogen content increases above the percentage present in the virgin state. Crop residues, like straw, which are low in nitrogen content have a depressing effect on nitrate accumulation and on yield when first applied, which is overcome only after the residue has decomposed to a point where enough carbon has been lost as carbon dioxide to bring the carbon-nitrogen ratio to about 11 to 1. Organic materials, when applied to the soil for the purpose of increasing the effective organic matter, are beneficial in proportion to their nitrogen content. Distribution of organic matter in the soil is influenced in a very pronounced degree by soil reaction. An alkaline soil solution tends to dissolve the organic matter and distribute it through a greater

depth of soil, whereas an acid soil solution precipitates the organic matter and thus prevents it from leaching into the subsoil. A high organic matter content in soils checks erosion by opening up the soil so that the moisture of precipitation is absorbed as rapidly as it falls.

The maintenance of a practically constant carbon-nitrogen ratio (10 to 1) in soils is ascribed by the New Jersey stations to the action of microorganisms. A wider ratio appears to result in nitrogen starvation and waste of carbon, a narrower in liberation of ammonia, thus tending to maintain a constant ratio. It is found that under aerobic conditions fungi are largely concerned in the decomposition of cellulose in the soil. The rapidity of decomposition depends largely upon the amount of available nitrogen, there being a definite correlation between the amount of cellulose decomposed by the aerobic microorganisms and the amount of nitrogen changed from an available form into microbial protoplasm, the ratio being about 30 to 1. When straw or other organic material rich in cellulose and poor in nitrogen was added to the soil, it was decomposed only to the extent that the nitrogen became available in the soil; and there was thus a competition between the growing plants and the soil microorganisms for the available nitrogen, and the cultivated plants suffered. The addition of available nitrogen in the form of ammonium salts or nitrates tended to prevent the injurious effect of a large quantity of straw upon the newly planted crop. Under anaerobic conditions the celluloses were decomposed by bacteria, and the nitrogen required in this process was considerably less than under aerobic conditions. It was found that some organisms broke down natural proteins largely to amino acids, while others decomposed these with rapid formation of ammonia. The decomposition of protein in the soil was thus the result of the combined action of at least two microorganisms.

Effect of manure and straw.—The Utah station found that the application of manure tended to widen the carbon-nitrogen ratio of the soil. It also increased the loss of calcium and magnesium from the upper layers of the soil. Magnesium carbonate was rendered more soluble than calcium carbonate, and hence the calcium-magnesium ratio was widened. The New York State station found that straw extracts exerted a harmful effect on plants even after sterilization, indicating that the effect is at least partly chemical. Certain organic compounds were isolated

from the straw extract, which showed a toxic effect on seedlings.

Lime and liming.—Sixty-mesh and 100-mesh limestone was found by the Delaware station to be as effective as burnt lime in decomposing organic matter in the soil, as measured by the carbon dioxide evolved. No difference was observed in the effects of the treatment on bacterial number or availability of phosphorus and potash. Limestone coarser than one-twentieth inch had little effect during the first two years after application, and that coarser than one-tenth inch was comparatively ineffective for three or more years, in greenhouse experiments at the Illinois station.

Nitrogen level of soils.—The results of eight years' studies at the Missouri station indicate that under Missouri conditions the nitrogen level of the surface foot can not readily be maintained above 4,000 pounds per acre. It is believed that providing a large revolving fund of nitrogen from crop residues, manure, and green manure is more important than maintaining a definite nitrogen level.

Nitrogen fixation.—The nodule bacteria of soy beans and red clover in dry soils stored for seven years in the laboratory were found by the Missouri station to be no longer viable but survived in soils in the field, indicating that a soil once inoculated will retain the organisms to reinoculate the legume as it recurs in rotation.

Bacterial counts in the field by the Washington station showed that as long as the moisture was approximately optimum and maximum daily temperature remained around 20 to 25° C. the number of nodule bacteria was fairly constant at 10,000,000 to 30,000,000 per gram of soil; but as the temperature increased and the moisture decreased a gradual drop in bacterial numbers occurred. During a period of three months, in which the maximum daily temperature frequently reached 30° and the moisture was between 1 and 2 per cent, the count remained fairly constant at 500,000 to 1,000,000 per gram of soil, but the number rose again when the fall rains came and the daily temperature again approximated 20 to 25°, showing that drought and heat have only a temporary effect.

Nonsymbiotic fixation of nitrogen in soils was increased by inoculation with cultures of the nitrogen-fixing organisms *Azotobacter chroococcum*, *A. vinelandii*, and *A. beijerinckii* prepared and tested by the Iowa station. Satisfactory methods of preparing the inoculating cultures have not yet been

worked out, and hence the method has not been put on a commercial and practical basis. It is suggested, however, that soil inoculation with *Azotobacter* may eventually become a profitable practice under actual field conditions. In the experiments here reported, inoculation with *Azotobacter* did not increase the yield of wheat, although there was an accumulation of nitrogen. The number of *Azotobacter* in the soil increased and decreased directly with the nitrates but generally inversely as the ammonia.

Ammonia and nitrate formation.—The power of soil microflora to produce ammonia from protein in acid reacting silty clay loam was found by the Oregon station to be little affected by the application of lime, plants capable of using ammonia thriving in these soils in proportion to the amount of decomposable nitrogenous organic matter. The production of nitrates from ammonia was greatly stimulated by moderate quantities of lime, indicating that plants requiring nitrates would be benefited by lime and probably would suffer from lack of nitrogen unless lime were added.

Nitrate production was comparatively slow, in experiments at the Nebraska station, at 5° C. and increased with the temperature, reaching its maximum at 35°, ceasing altogether at 55°. It was insignificant at moisture contents as low as the hygroscopic coefficient of the soil, but increased with the moisture content up to the highest point measured, one and one-fourth times the moisture equivalent.

From a study of the depressive effect of plant residues on the nitrate content of soil, the New York Cornell station reached the conclusion that this is due to stimulation by the plant residues of the action of soil organisms which assimilate and transform the nitrates into other forms of nitrogen. The rate of depression varied with the kind of plant material, being more prolonged with timothy residues than with clover residues, due to the greater ease and rapidity with which the latter is decomposed and assimilated by the organisms and their consequent more rapid multiplication and growth.

Many of the soils of Colorado contain nitrates in sufficient quantities to be injurious to crops. The station's investigations indicate that in many cases this nitrification is due to the combined action of vigorous nitrogen-fixing, ammonifying, and nitrifying organisms stimulated by high summer temperature, clean culture, abundant moisture, and a favorable soil reaction.

of pH 7.4 to 7.6. The nitrogen-fixing organisms apparently derive their energy from soil algae, of which some 21 species have been identified. There is a greater accumulation of nitrate during the growing season under cultivated than under uncultivated crops. This unusual situation makes necessary the finding of means to restrain nitrification, and different crop rotations have been studied with this object in view. The application of either sulphur, acid phosphate, or green manures appears to improve the quality and yield of sugar beets on the high nitrate soils. On fallow land excessive formation of nitrate has been controlled by the use of sulphur.

Loss of nitrates by leaching.—Experiments reported by the Alabama station indicated that the loss of soluble nitrogenous fertilizer by leaching may be reduced by delaying the application until the crop will absorb it rapidly. Nitrate of soda applied to oats at the rate of 400 pounds per acre 42, 70, and 92 days after planting was found completely absorbed in 20, 14, and 10 days, respectively. Applied to cotton at the rate of 600 pounds per acre 14, 40, and 61 days after planting, the nitrate was absorbed in 36, 14, and 11 days, respectively.

Heavy additions of lime were found by the Tennessee station to be initially repressive of nitrate outgo in lysimeters, to the point of inhibition, but the residual effect was to produce a very heavy loss of nitrate nitrogen. Sulphur, either as ferrous sulphate, pyrite, or elementary sulphur, caused a depression in nitrate outgo. Very heavy additions of magnesium oxide proved less active than corresponding additions of calcium oxide in promoting nitrate losses.

Availability of nitrogenous fertilizers.—Experiments made by the New Jersey stations confirm the fact that plants use nitrogen very rapidly in the early stages of growth and emphasize the importance of having a supply of available nitrogen ready for the plant when it is starting to grow, especially in the early spring when nitrifying processes are slow. In the New Jersey experiments the average utilization of nitrogen by the plant was 62.6 per cent in case of nitrate of soda, 54.24 per cent in case of ammonium sulphate, 46.62 per cent in case of tankage, and 25.84 per cent in case of calcium cyanamide.

Sulphur.—Large applications of lime to the soil were found by the Tennessee station to practically inhibit outgo of sulphates in lysimeter leachings, but

this effect was not permanent. The retention of sulphates in heavy limed soils is explained by the formation of the ternary systems $\text{CaO}-\text{Fe}_2\text{O}_3-\text{CaSO}_4$ and $\text{CaO}-\text{Al}_2\text{O}_3-\text{CaSO}_4$. The sulphur content of soils was found by the Illinois station to be correlated to some extent with that of organic matter. In the tests made the amounts of sulphur in the surface soil ranged from 100 pounds per acre in ordinary soils to several thousand pounds in certain peaty soils, averaging from less than one-half to three-fourths as much as phosphorus. Without the sulphur added by rain the soil supply would probably be inadequate for normal growth of crops.

Sulphur and gypsum increased the yield and nitrogen and sulphur content of alfalfa and clover in experiments at the Washington station. There were indications that the chief beneficial action of sulphur was to aid the nodule bacteria in supplying more combined nitrogen to the plant. The sulphur was most effective when applied as a top dressing. In a study of the effect of sulphur and gypsum on Palouse silt loam, this station found that the soil had a naturally high sulphurying power, and uninoculated sulphur was just as efficient as inoculated in producing sulphates. The gypsum and sulphur were readily leached out during the winter months. They also increased the availability of the soil potash under greenhouse conditions. Sulphur oxidizing in the soil increased the loss of soil calcium. Magnesium was but little affected by either sulphur or gypsum. Nitrification was but little affected by either. Sulphur applied to alfalfa gave no marked increase in yield or root development, in experiments at the Kansas station, indicating that sulphur is not the limiting factor in alfalfa production on the type of soil used. In general, the acidity of the soil was increased by the application of sulphur.

Application of inoculated sulphur increased soil acidity and resulted in brighter and cleaner potatoes, with a higher percentage of primes, in experiments at the Delaware station. There was also evidence that the sulphur treatment improved the keeping quality and retarded development of black rot and soil stain but not of Fusarium wilt.

Subsoil potash.—Pot experiments with millet grown on different layers of soil at the Massachusetts station indicated that the potash of the deeper subsoils is either more available or more abundant than that of shallower subsoils,

and in this case was sufficient for maximum production. The availability of the potash was measured by the percentage of potash in the crop.

Soil erosion.—The Missouri station found the erosion from soy bean land having a slope of 3.68 per cent to be 86 times as great as from sod land and 84 per cent as great as from land continuously in corn. Nitrogen was lost in the eroded soy bean soil at the rate of 32 pounds per acre annually.

Maintenance of fertility.—Thirty years' results of the carefully planned and executed field experiments of the Ohio station on maintenance of soil fertility have recently been summarized. The experiments were made at five different places on as many types of soil. The outstanding facts brought out are that acid phosphate is especially profitable as a fertilizer for wheat, that corn is more responsive to potash than wheat, that the use of nitrogenous fertilizers in a rotation containing a legume is not likely to be profitable, and that liming is largely and widely profitable under the conditions of these experiments.

Manure and crop residues.—The proportion of the fertilizing constituents in the feed recovered in the manure of dairy cows was found by the South Dakota station to vary decidedly. More potash and nitrogen was recovered in feces than in urine. The nitrogen, phosphoric acid, and potash recovered varied with the type or breed of the animal and with the daily milk production. In a very general way, the recovery of potash and nitrogen was in inverse relation to milk production, while the phosphorus recovery paralleled the production of milk.

In a comparison made by the South Dakota station of turning under all crop residues (cornstalks, oat straw, and clover humus), in a rotation, with harvesting and feeding these residues and returning the equivalent in manure, higher yields were secured in the first year from the manure plats, but the yields of later years were higher from the plats where crop residues were turned under directly.

PLANT PHYSIOLOGY AND NUTRITION

Photoperiodism.—Extending to beans and sweet potatoes work of the same character as that previously done with *Tephrosia candida*, the Porto Rico station found, as in the case of *Tephrosia*, striking differences in growth with varying lengths of day. Investigations by the Minnesota station showed that when illumination was constant the growth rate was constant and indicated that the usual differences of growth by day and night were not caused by in-

ternal rhythm. The rate of growth and fluctuations in the supply of nutrients produced during the illumination period seemed to be related to the production of bloom and seed and was evidently due to the reaction of the plant to the length of day. Many plants apparently do not require a particular length of day for blooming.

Plant metabolism.—A study of the distribution and rôle of phloridzin in apple and pear tissue by the Oregon station showed the greatest quantity of phloridzin in such tissue in the early summer, the period of highest metabolic activity. At this period phloridzin may increase to 20 per cent of the total solids, or 5 to 6 per cent of the fresh weight of the tissue. It was found to be most abundant at the tip of the shoot and uniformly less toward the base. The general speculative conclusion is "that the phenol acids, upon which the synthesis of phloridzin depends, are a sort of by-product of metabolic activity, and that phloridzin serves as a protection against an accumulation of these substances or as a temporary repository of them for future use by the tissue. The possibility of a direct rôle of phloridzin as an accelerator of vital processes was indicated." An improved hydrolysis method of determining phloridzin is reported.

Plant colloids.—Potato tuber and other kinds of plant tissue were found by the Missouri station to act much like amphoteric colloids, with isoelectric points as follows: Potato-tuber tissue pH 6.4, soy bean root tips (variety Virginia) 6.2 to 6.44, the mycelium of *Gibberella saubinetii* 6.2, the mycelium of *Fusarium lycopersici* 5.5, and the mycelium of *F. oxysporum* 4.9.

Nitrogen fixation by nonleguminous plants.—That nonleguminous plants fix nitrogen through nodules on their roots is indicated by observations reported by the Michigan station on a number of nodule-bearing nonleguminous plants of that State, notably *Ceanothus*, nodule-bearing plants of which were found to contain more nitrogen than those free from nodules.

Nitrogen assimilation.—In experiments at the New Jersey stations it was found that in solutions containing both NO_3^- ions and NH_4^+ ions, soy beans, in the early stages of growth, absorbed nitrogen in the form of NH_4^+ at a higher rate than in the form of NO_3^- . During the later stages of growth this was reversed. Corn in the very early stages of growth absorbed no measurable quantity of nitrogen in the form of the NO_3^- ion, but obtained its nitrogen as NH_4^+ when both were present. In later stages both NO_3^- and NH_4^+ ions were absorbed. The pres-

ence of an ammonium salt in the culture solution increased the nitrogen content of the plants over that of plants grown in a culture solution in which the nitrogen was present in the form of a nitrate in equivalent concentration of nitrogen; but this excess nitrogen in the plant did not affect the protein nitrogen content, which remained approximately constant, the excess nitrogen being in the nonprotein form. The stations also found that the high nitrogen content of the soy bean plant following the addition of calcium to soils or culture media bore no relation to the protein nitrogen, the increase being due to nonprotein nitrogen. A higher content of both nitrogen and calcium in the plant occurred in the presence of calcium carbonate than in the presence of nitrate or chloride. The higher nitrogen content of the plant was definitely correlated with relatively low hydrogen-ion concentrations.

Germination of wheat seedlings.—In the early stages of germination of wheat the ether extract was found by the Iowa station to disappear from the seed more slowly than the carbohydrates or proteins. The amount of sugar increased rapidly during the first six days. After 12 days the plants appeared to be dependent upon photosynthetic activity. Wheat seedlings required relatively large amounts of mineral nutrients.

GENETICS

Station work in both plant and animal genetics showed an increase during the year. Over 125 genetics projects were recorded as in active operation at the stations during the year. A few examples of recent work in this field are briefly noted, as follows:

Sterility in apples.—A cytological study, by the Minnesota station, of pollen development indicated that in the Stayman Winesap variety poor pollen is a result of irregular chromosome distribution at maturation, combined with several types of degeneration in the microspores and pollen grains. The evidence is indicative of a hybrid condition in this variety. Controlled pollination of stigmas of the pistils of two varieties, as well as cytological evidence, showed that pollen tubes pass from one carpel to another. The course of growth of the pollen tube is from the stigma through the conducting tissue of the style to the placenta, where it may fertilize the ovules of the carpel or pass between the edges of the carpel and over the base of the central cavity and enter another carpel through its suture.

Heterozygosis in the Jonathan apple.—The Jonathan apple was found by the Iowa station to be heterozygous to almost every set of factors determining size and form of fruit, flesh texture, flavor, and season. Jonathan apple combined with red varieties gave some solid red seedlings; when combined with yellow and blushed varieties the color tones were diluted to produce striped, mottling, and dull shades. Attempts to introduce the vigor and health factors by crossing Jonathan with other varieties resulted in seedlings showing a heterozygous condition for this factor with promise of some excellent strains.

Size and yield inheritance in beans.—Studies by the Maine station showed that differences in size and total yield of beans are to some extent at least dependent on genetic factors linked with factors for simple qualitative differences and are therefore inherited in the usual Mendelian manner. Yield was associated with single color and pattern differences. Factors for yield were found to be unequally influenced by environmental conditions.

Linkage relations of yellow pigment in maize.—The discovery of two genes responsible for the formation of pigments in maize, both recessive and strictly following Mendelian inheritance, was reported by the Iowa station. Linkage tests showed that both genes are borne on the same chromosome. Interactions of the genes with the albino genes indicate a fundamental, physiological (or chemical) difference in the yellow pigments of maize, so that one yellow pigment is considered to be independent of the green components of chlorophyll in development and the other not.

Transmission of chemical characters in corn.—Chemical properties such as carbohydrate content were found by the Iowa station to follow a definite system of hereditary transmission. It was shown to be possible to cross sweet corn with field corn to increase the yield without reducing the sugar content of the sweet corn.

Linkage groups in barley.—Of the 7 expected linkage groups of the 14 somatic chromosomes of barley, 4 have been established by the Minnesota station. Resistance to *Helminthosporium sativum* was shown to be due to definite genetic factors, in case of the Svanhals type there being probably at least three factors, one linked with the factor for 2-rowed, one with the factor for rough awns, and one with the factor white glumes. "The factor for early heading was found to be linked with the factor

for 6-rowed. The linkage intensity was very low, the crossover value being 42 per cent. The linkage of the factor for susceptibility to *Helminthosporium* with the factor for earliness is much more intense than that with the factor for 6-rowed, else earliness in itself predisposes the plant to attack by the pathogen." According to the same station *Hordeum* species generally fall into three groups in regard to chromosome numbers, the first having 7 pairs and including all of the cultivated species, the second having 14, and the third 21.

Linkage in wheat.—A count of 60 F_2 plants of a cross of Khapli-Mindum \times Marquis, by the Minnesota station, showed plants with 14 bivalents and 21 bivalents and univalents to be most frequent. Webster, which is resistant to stem rust, showed 42 somatic chromosomes. Color of grain in Marquis wheat appeared to be the result of two duplicate genes, and grain color in Kanred and Minturki was apparently due to a third independently inherited factor.

Chlorophyll deficiencies in cotton.—Two heritable deficiencies in green coloring matter in cotton seedling, namely, yellow seed leaves instead of the usual green and lack of green color in certain portions of the seed leaves, are reported by the Texas station. The presence of two recessive genetic factors Y_2 and y_1 is shown to be necessary for the expression of this character. One, two, and possibly three different genetic factors, that is, 3:1, 9:7, and 27:37 ratios, were found present in different and in the same families. Also there is a slight possibility that two of these factors are linked.

Chromosomes in potatoes.—The Maine station found 24 haploid chromosomes in commercial varieties of potatoes. Some of the varieties showed lagging chromosomes at the time of the reduction divisions, indicating hybrid origin. In other commercial strains the chromosomes were orderly in their behavior. The chromosome number in wild species varied from 12 to 36, being in all cases multiples of 12.

Sex in spinach.—Sex expression in spinach appears, from studies made by the California station, to be not affected by physiologic factors. Time of planting, light intensity, plant food supply, and spacing of the plants apparently do not alter the sex ratio. That sex is controlled by genetic factors is indicated by the fact that monoecious plants of varying degrees of "maleness" or "femaleness" occur, and these pro-

duce in their progeny many monoecious plants with the same degree of sex expression as the parent plant. See p. 31.

Inheritance and evolution in the grouse locust.—A fifth contribution was made by the Kansas station to studies begun in 1906 of inheritance and evolution in Orthoptera, using the grouse locust as material for the study, because of their many strikingly contrasting characters and the ease and rapidity with which genetic studies can be made with them.

Sex control in animals.—Sex control by centrifugal separation of male-producing and female-producing spermatozoa seems possible, according to results of experiments with rabbits and swine reported by the Wisconsin station, for species in which the difference in the sizes of the X-chromosome and the Y-chromosome is a considerable percentage of the total amount of chromatin in the spermatozoa. Whether such a method can be made practicable even for the most favorable species depends upon the possibility of making the technique simple and dependable.

Inheritance of body weight in fowls.—In experiments with Cornish-Hamburg crosses, the Rhode Island station found that both the first and second generation offspring from the cross developed at the same rate as the Cornish breed and attained the same weight at 10 months. Later, however, the Cornish fowls increased in weight slightly faster than the crossbreds. The crosses in both the first and second generations were not more variable than the parents.

Sexual maturity and egg production.—The Missouri station reports investigations which showed that quick-maturing pullets are superior egg producers and make the best winter egg records. There was a slight but perceptible negative correlation between rate of sexual maturity and spring egg production, less variability in spring production than in winter or summer production, and a slight negative correlation between rate of sexual maturity and summer egg production. Little, if any, correlation occurred between rate of sexual maturity and rate of laying as measured by the best month's production or best two months' production.

Inheritance of fecundity in hens.—Results of investigations at the New Jersey stations showed the existence of a winter cycle of egg production for Leghorns similar to that reported by the Maine and Massachusetts stations for Barred Plymouth Rocks and Rhode Island Reds. The investigations indicated the absence of linkage in the inheritance of fecundity.

FIELD CROPS

Of the approximately 5,500 projects reported as active at the experiment stations, over 1,800 dealt with field crops, covering various phases of the improvement, culture, and handling of the principal crops.

Time to cut alfalfa.—The Minnesota station found that alfalfa cut in the hard bud stage four times during the season was not seriously injured. Although earlier cutting than the tenth bloom is not advised as a general practice, if the first crop makes so rank a growth that lodging is apt to result it may be cut before tenth bloom, in order to secure a better quality of hay with no injury to the stand; and later cuttings can be made at tenth bloom.

Improved varieties of barley.—A pure-line selection made by the Minnesota station from an importation which was received under the name of "Switzerland" has, for several years, often yielded 50 to 100 per cent more than any other barley tested. This has been named "Peatland" and is to be increased for distribution. Colsess, a new 6-rowed, hulled, hooded barley produced by the Colorado station as a result of a cross between Coast, a bearded sort, and Success, a beardless or hooded sort, has shown in tests at the station several advantages over other Colorado barley, namely, in yield under irrigation, stiffness of straw, earliness, loss due to shattering, and adaptation to mountain agriculture.

Mat bean as a green manure crop.—The mat bean (*Phaseolus aconitifolius*) was found by the California station to be well suited to use as a leguminous green manure and cover crop for vineyards and orchards, to protect the soil from the hot sun, to prevent the burning out of organic matter, and to leave the irrigation furrows visible and accessible. It is also a drought-tolerant plant which provides pasture and improves the soil and can be rotated with grain.

Corn selection.—The Illinois station found that after 28 years of selection the protein content of corn was raised from 10.92 to 16.6 per cent in the high strain and lowered to 8.38 per cent in the low strain, and the oil content was increased from 4.7 to 9.86 per cent and lowered to 1.51 per cent. Selection increased the height of ear from 49.6 to 92.9 inches and lowered it to 11.7 inches. The yield of a strain was increased 5.6 bushels per acre in 3 years by mass selection, which proved just as effective as continuous ear-row selection.

Time to cut corn.—The Ohio station found that corn cut in the dough stage

yielded 42 bushels per acre, when the kernels were fairly hard and ready for the silo 68 bushels per acre, and when mature 78 bushels per acre. The station therefore concludes that feeding immature corn to hogs is a wasteful practice.

Water requirements of corn.—In potometer experiments at the Missouri station with corn grown on fertile soil with varying amounts of moisture during different periods of growth, it was found that the moisture supply during the second period or from the time the plants set their ninth leaves until about tasseling time had by far the greatest effect upon the total dry weight of the plants. Plants stunted by minimum moisture (13 per cent of the soil capacity) during the first period were able to recover and produce good plants, if conditions were favorable during the last two periods, but the time of maturing was somewhat prolonged. Minimum moisture during the third period gave a greater weight of root growth than optimum moisture (28 per cent). In all periods minimum moisture gave a greater root growth in proportion to tops than did optimum, even though the actual weight was less during early growth. Optimum moisture during the third period gave considerably greater production of grain than did the low soil moisture content. The quantity of water transpired per unit of dry matter produced varied greatly in different years with variation in the weather conditions. Variation in transpiration with different treatments was not great, but was slightly less with low soil moisture. In practically all cases the plants contained a higher percentage of nitrogen and mineral elements where the moisture content of the soil was low. The Nebraska station found inbred strains to be less efficient in their water economy than hybrids.

Irrigation of corn.—The maximum yield of corn was obtained by the Utah station with 20 inches of irrigation water. Manure somewhat lessened the loss due to either insufficient or excessive irrigation, and optimum irrigation was found to be especially needed when manure was insufficient. The nitrogen content of corn grown on a highly calcareous soil was decreased by irrigation and increased by manuring. The mineral constituents of the grain were increased by both irrigation and manuring.

Drought-resistant corn.—Drought resistance in corn was found by the Porto Rico station to be correlated with thickness and intensity of color of the leaves, and use is being made of this fact in selecting drought-resistant seed corn.

Foreign v. domestic clover seed.—Germination tests by the Delaware station of red clover seed from nine domestic and foreign sources showed no appreciable difference, but the stand was better with domestic seed. Clover from foreign seed was more susceptible to anthracnose and winterkilling, while American clover was more susceptible to powdery mildew. Medium red clover from seed obtained from Italy, France, Chile, England, and Wales was completely killed, in tests at the Minnesota station, during the winter of 1924-25. Stands from seed from Germany, Austria Hungary, and adjoining countries came, through in fair condition, and plantings from northern-grown American seed were not injured.

Lint and seed characters of cotton.—In a statistical study of 16 varieties of cotton, the Texas station found in all varieties positive correlations between yield of lint and seed, yield of 5-lock bolls, yield of seed and number of 5-lock bolls, yield of lint and number of 4-lock bolls, and yield of seed and number of 4-lock bolls. No consistent relation was shown between yield of lint and percentage of lint, yield of lint and length of lint, yield of seed and percentage of lint, yield of seed and length of lint, percentage of lint with length of lint, nor with the percentage or length of lint with either 5-lock or 4-lock bolls.

Delinting cotton seed.—The sulphuric acid treatment for delinting cotton seed was found by the Arizona station to be very effective. The station has devised a machine which applies the method quickly and thoroughly and makes the use of sulphuric acid safe for the operator. The treatment results in surface sterilization of the seed, hastening of germination, increased percentage of germination, greater ease in handling the seed in planting, and a healthier and more uniform stand. Cooperative treatment in a central community plant is recommended. The North Carolina station found that delinting with either sulphuric acid or machinery hastened germination. The acid treatment also reduced disease in the seedlings.

Spacing cotton.—Spacing tests by the South Carolina station showed that closely spaced cotton not only produced larger yields but a much earlier crop and resulted in a change of practice to a marked degree. Cotton spaced 24 inches apart in the drill yielded 1,035 pounds of seed cotton, while 9-inch spacing yielded 1,336 pounds.

Improved flax culture.—The production of flax in the United States declined to a marked extent during the period from 1909 to 1921, but has greatly increased in recent years, according to the South Dakota station. The development and use of disease-resistant varieties have aided in overcoming one of the greatest handicaps to successful flax growing. Careful selection of soil, seasonal seeding, and use of the proper amount of seed are other important considerations. Seeding flax and wheat together was found by the station to have some possible advantages under certain conditions, but the station does not undertake to recommend this as a universal practice. The Minnesota station found that a combination of wheat 45 pounds and flax 42 pounds gave the highest gross returns per acre, \$35.22. Flax sown at the rate of 42 pounds per acre alone gave a gross return of \$32.79.

Wilt and rust resistant flax.—The Minnesota station found that wilt-resistant varieties do not lose their resistance by being grown on clean soil. Several Argentine fiber strains immune to rust were crossed with seed types, and the F₁ of all crosses have so far been immune, indicating that resistance is dominant. Segregation occurs in the F₂ plants, the majority being immune. There appears to be no correlation between wilt resistance and rust resistance.

Improved varieties of oats.—Improved varieties of oats developed and distributed by the Iowa station, including Iowa 103, Iowa 105, Iowar, and Iogren, it is claimed, are "returning to the State annually more than the total annual appropriation made by the State for the support of the Iowa State College and experiment station combined; more than 15 times the amount appropriated by the State to all of the work of the agricultural experiment station; more than 200 times the funds expended on all the crop improvement work." A survey made in 1924 indicated that 46 per cent of the total oat acreage in Iowa was planted to the 4 pedigree varieties named. Iowa 103, first distributed in 1913, giving an average increase in yield of 3.73 bushels, was grown on 23 per cent of the oat land; the Iowar, distributed in 1919, giving an increased yield of 5.93 bushels, was grown on 15 per cent of the land. The total increase in production resulting from the growing of these varieties in 1924 is estimated to have been 11,000,000 bushels.

Natural crossing of oats.—The Minnesota station found that the extent of nat-

ural crossing in oats varied with the variety but was not greatly modified by seasonal conditions. The largest percentage of offtypes obtainable was 1.4 per cent in the case of Kanota. Every variety showed some natural crossing. Natural crosses occur somewhat less frequently in oats than in wheat.

Variants of the Burt oat.—The commercial Burt oat, according to the Kansas station and the United States Department of Agriculture, is composed of a large number of distinct strains, many of which are heterozygous. The variety is considered to belong to *Avena byzantina*. Field crosses are apparently frequent. It was found that this oat varies "in many observable plant characters, such as habit of growth of the young plant, leaf color and leaf width, time of heading and ripening, and others. Several distinct variants have been observed, among them one showing a chlorotic condition of the leaves, one having multiflorous spikelets, one with loose paleas, and the false wild forms."

Smut resistance in oats.—The glumes of oats were found by the Kansas station to be a great natural protection to the seed of varieties susceptible to smut, such as Aurora, Richland, Burt, and Kansas 6004. Resistant varieties such as Burt, Kansas 6090, and Kanota are inherently resistant; that is, their resistance is not due to such a large extent to the natural protection afforded by the glumes. Smutted Aurora seed, the glumes of which were not removed, gave 15.1 per cent of smutted heads, while seed from which the glumes were removed gave 56.7 per cent. Resistant Kanota seed, with the glumes not removed, gave 2.7 per cent of smutted heads and 4.5 per cent when the glumes were removed.

Pastures.—Permanent improved bluegrass pastures are, according to the Pennsylvania station, worthy of a more prominent place in economic farm management in regions suited to this grass and should largely eliminate the necessity of growing expensive leguminous soiling crops as supplementary dairy feed. The maximum growth of bluegrass was obtained, in the experiments reported, on soils treated with limestone and a complete fertilizer. Over three times as much crude digestible protein was produced with complete fertilizer on pasture as was produced on the same acreage in a grain rotation.

Burning over of upland pastures during the dry season was found by the Guam station to kill the valuable

grasses and allow worthless weeds to take their place. Similar results are reported by the Kansas station. In experiments by the Connecticut Storrs station, lime alone produced no increase the first year, whereas acid phosphate increased the yield of pastures, as measured in pounds of beef maintained or gained, by 45 per cent.

For pastures on hilly land, orchard grass, tall meadow oat grass, red fescue, and sweet vernal were found by the Maryland station to be a very satisfactory mixture, with white clover and lespedeza added for the slopes and mountain valleys. Kentucky bluegrass and orchard grass proved best for pastures. For hay, the tests showed that a combination of alsike clover, alfalfa, and timothy was more profitable for yield and quality than clover and timothy alone.

Seed peas.—The production of seed peas is one of the most important seed-producing enterprises in the United States. The raising of seed peas has been one of the notable agricultural developments in the Northwest. The Montana station, among others in that region, has given much attention to the subject and has recently published detailed instructions for the culture of peas for this purpose, based upon extensive observations and experiments.

Field tests with potatoes.—The technique of field experimentation and the reliability of field experiments are receiving increasing attention. In a study of the experimental error in field tests with potatoes, the West Virginia station found the results to substantiate the conclusions drawn from similar work with other crops; that is, that there is a limit in plat size and number of replications beyond which no practical reduction in experimental error occurs, and that reliable results under West Virginia conditions with potatoes planted 10 to 12 inches in the row and the rows spaced 3.5 feet apart may be expected from the use of a 40-foot single-row plat replicated four times.

Alaska seedling potatoes.—Seedling varieties of potatoes showing marked improvement over standard sorts have been originated by the Alaska stations. The selected seedlings mature early, yield well, and produce large, smooth-skinned tubers of good shape and cooking quality.

Size of seed piece of potatoes.—In experiments at the Montana station, size of tubers varied inversely with the size of the seed piece, small seed pieces resulting in a higher percentage of large tubers, whereas large seed pieces gave

an increase of average-sized tubers. Under irrigation 3-ounce seed pieces gave best results, whereas under dry-land conditions 2-ounce pieces were best.

Storage temperature for potatoes.—From a study of respiration in potatoes, the Maryland station concludes that 40° F. is apparently the best storage temperature. Respiration in potatoes removed from storage at 40° to market temperatures was abnormally high but not half as high as in potatoes removed from storage at 36°. The station concludes that temperatures above 40° can hardly be considered practicable for late storage because the tubers will not be kept sufficiently dormant at this temperature.

Uses and value of the soy bean.—After 15 years' investigation and observation, the Iowa station concludes that the soy bean has more uses in Iowa than any other legume and is well adapted to the climate and soils of the State. It grows well on distinctly acid soils and is a safe and dependable crop. Of 157 varieties tested, Manchu is especially recommended for seed production and Peking for hay and silage. Twice as much seed per acre as is ordinarily recommended has consistently given the most profitable yields of seed and hay. Two bushels of seed per acre of the most commonly grown varieties is recommended when the crop is drilled. Soy beans may be grown alone or in combination with corn. They may be fed advantageously to dairy and beef cattle, sheep, hogs, and chickens to replace, at least partly, such feeds as oil meal and tankage. The soy-bean plant appears to have approximately the same feeding value as alfalfa and may be used in the form of hay, pasture, silage, or soilage, while the seed furnish an excellent protein concentrate.

Yield of soy beans.—Soy beans yielded more than four times as much seed and more than twice as much hay as cowpeas, when grown in rows 42 inches apart, in experiments at the Missouri station. When sown with an 8-inch grain drill, the yield of soy-bean hay was again more than double the yield of cowpea hay, and the yield of seed was 32.2 bushels per acre, whereas the cowpeas yielded less than 3 bushels.

Soy beans and corn.—A combination of soy beans and corn produced an average increase of approximately 1 ton of green forage and 500 pounds of dry matter per acre over corn alone, in experiments at the Connecticut Storrs station. The mixture harvested averaged 1.82 per cent protein and contained 670 pounds per acre, whereas the corn silage averaged 1.54 per cent protein and con-

tained 550 pounds per acre. The experiments indicated that approximately \$10 per acre will be added to the value of the silage by planting soy beans with corn.

Improvement of soy beans by selection.—The North Carolina station found that selecting soy beans for high yield is more important than selecting for high oil. High oil and low protein content are usually associated and vice versa.

Soy bean inoculation.—The soy bean radicicola organism, according to the New Jersey stations, does not tend to become adapted to specific host varieties of soy beans. The differences in nodulation found in several varieties of soy beans appeared to be due to some physiological difference in the varieties, possibly in ability to conduct carbohydrates to the roots or proteins away from them. In a study of the effect of bacterial numbers on the nodulation of Virginia soy beans the New Jersey stations found that "when the number of nodular organisms is limited there is a distinct relation between the number of organisms present and the number of nodules formed. There is a rather definite minimum number of nodular organisms required to produce maximum infection. After a certain degree of infection is reached the host is immune to additional infection."

No legume had been found by the Illinois station which consistently cross inoculates with the soy bean. Under laboratory conditions some strains of cowpea bacteria apparently had the power to cause infection on the soybean plant. A large number of previously unclassified legumes were found to belong to the cowpea group. Certain varieties of soy beans were apparently less susceptible to bacterial nodule infection than others. The total weight of nodules on a plant is thought to be a better index of its nitrogen-fixing ability than the number of nodules present. The strain of bacteria was also found to be an important factor. Inoculation and liming materially increased the yield of soy beans on acid soils which were not in a high state of fertility. A combination of the two gave a more satisfactory return than either alone. The protein content of the soy bean was greatly increased by inoculation.

Imported sugar beet seed.—Michigan-grown sugar beet seed from unselected commercially grown foreign seed gave beets of comparatively high tonnage, low sugar content, and low purity, in experiments reported by the Michigan station. Beets grown from many of the foreign seeds differed materially in their

producing power. Since the Michigan beet sugar industry is largely dependent upon foreign grown seed, the importance of developing strains which will give not only high tonnage but high sugar content and purity as well is evident.

Mosaic-resistant sugar cane.—Progress in developing an improved mosaic-resistant strain of Japanese sugar cane and encouraging the growing of such cane is reported by the Porto Rico station. Soaking seed cane for three or four days in limewater was found to destroy stalk borers and stimulate germination and early growth.

Paper mulch for sugar cane.—Paper mulch increased the tonnage of plant cane at the Virgin Islands station but not enough to pay for the paper.

Sunflowers with corn for silage.—A mixture in the proportion of 1 bushel of sunflower seed to 8 of corn gave an average yield of 19.5 tons per acre, in experiments at the New Hampshire station. The sunflowers increased the tonnage materially but increased the cost of harvesting, the heavy heads breaking the stalks and increasing the cost of loading and putting them through the cutter. There was no disadvantage in feeding the mixed silage from the standpoint of milk production, and the cows ate it as readily as they did corn silage.

Cover crops and rotations for tobacco.—The Maryland station found that the frequent and persistent use of soil-improving crops such as vetch, cowpeas, and crimson clover, either with continuous culture of tobacco or in short rotations, did not give as uniformly good yields and quality of tobacco as does the old system of resting the plant for a period of years after one or more crops of tobacco.

Timothy as a cover crop proved harmful to tobacco in experiments at the Massachusetts station, probably partly due to an increase of brown root rot under the crop.

Chemical constituents of different grades of tobacco.—In a study of the relation of certain constituents of tobacco to grade, the Kentucky station found that the best tobacco of any grade usually contained a larger percentage of nicotine than the common. The nitrogen and nitrate were more variable but in the majority of cases were higher in the good tobacco than in the common. In the Burley grades the fillers usually contained the largest percentages of nitrogen and nicotine and the smokers the smallest. In dark tobacco the leaf usually contained the largest percentage of nitrogen, nicotine, and nitrate, and the trash the smallest. There was

considerable variation in the ash constituents of different grades, but apparently the good grades contained most potash.

High-protein wheat.—A study by the North Dakota station of the protein content of hard red spring wheats over a period of 15 years showed that climatic conditions are an important factor in determining the protein content of the crop. Low temperature during the growing season produced low-protein wheat, whereas high average temperatures during June and July produced high protein. Rainfall variation was not as important as temperature, but wheat in seasons of very low rainfall was high in protein. Soil fertility and preceding crops affected the protein content, and by the use of legume crops such as clover, sweet clover, and alfalfa, high-protein wheat was produced in seasons when climatic conditions favored the production of low-protein wheat. The relative protein content of different varieties showed variations in different sections of the State, evidently due to the reaction of the variety to climatic conditions.

Hard grain strains of wheat have been isolated by the Arizona station from a soft strain of Early Baart. These strains grown for four years under irrigation were fully as hard as the grains originally selected. Flour of these hard strains was about 6 per cent higher in absorptive power and about 2 per cent higher in gluten content than that of the soft parent. Apparently the quality of the gluten was not materially improved, because the loaf volume was not increased, although the bread yield was increased as a result of the greater absorption.

In a study of correlation between the capacity of wheat to increase its protein content under fertilization with nitrate of soda and of the two heritable properties of ratio of grain to total weight and capacity to ripen after treatment, the California station found evidence of such correlation in a considerable number of varieties. The protein content was markedly affected by manipulation of the supply of the nitrogen in the growth media, but evidently there were other factors which probably affected the rate of supply of nitrogen to the plants.

Length of head and yield of wheat.—Selection of long heads of wheat in the field is not a means of increasing the yield of a variety, according to investigations reported by the South Dakota station. Length of culm was correlated with the length of head that it bore, but there was no correlation between length of head and the length of culm produced by these heads in the succeeding gener-

ations. Long heads were as a rule borne on long culms, but seed from long heads did not necessarily give plants with long culms. The highest average yield of Marquis wheat for four years was obtained from strains that came from mother heads of 11.5-centimeter length.

Pollen production by wheat.—Different varieties of wheat vary in the amount of pollen produced, according to studies reported by the North Dakota station. There appeared to be a close relationship between length of anthers and pollen-bearing capacity.

Green manures for wheat in Alaska.—Wheat gave a larger yield following potatoes than after various leguminous green manures, in experiments reported by the Alaska stations. This is attributed to exhaustion by the green manure crops of the soil moisture, which was limited by deficient rainfall.

Effect of irrigation on mineral constituents of wheat.—The iron content of wheat was found by the Utah station to increase with the quantity of irrigation water applied during the growing season. Wheat grown with 35 inches of irrigation water contained 169 times as much iron as did similar wheat grown without irrigation. The chlorine content of wheat was found to vary directly with the amount of water applied during the season. Wheat receiving 35 inches of water contained 27 times as much as that without irrigation. The sulphur content of wheat also increased with quantity of water applied.

Irrigation requirements of crops.—The New Mexico station obtained the best results with alfalfa from about 50 inches of water applied in 5-inch irrigations; with wheat, from about 15 to 20 inches, applied in 4-inch irrigations. With various other crops the duty varied widely with the crop. The irrigation season for alfalfa was about 6.5 months, and for wheat, about 8.5 months, from October 4 to June 15. The irrigation season for the other crops grown was between February 21 and October 25, depending on the crop. The yield of most of the crops included in these investigations seemed to be more closely correlated to the amount of water applied than to the soil type. The yield of alfalfa per acre-inch decreased with amount of water applied. The yield of wheat per acre-inch varied from 27 to 201 pounds.

Weight of seed.—In soil cultures by the New Jersey stations with soy beans, buckwheat, Lima beans, and corn, seeds of high medium weight produced better plants, from the standpoint of several quantitative plant measurements, than did seeds of lighter weight or abnor-

mally heavy seeds, but the superiority of plants grown from heavier seeds over those grown from lighter seeds decreased notably as the plants approached maturity, sometimes disappearing entirely.

Weeds and weed control.—Destruction of weeds is the principal benefit of cultivation of corn on the brown silt loam soils of Illinois, according to the Illinois station, and for this purpose shallow cultivation is preferable to deep. Deep cultivation of corn may result in root injury and decreased yields. Weedy corn probably suffers more from a lack of nutrients than from deficiencies of moisture under the climatic conditions under which these experiments were made. Need of cultivation seems to be no greater in dry than in wet years; it may, in fact, be less.

Weed killing, according to the Missouri station, should be the chief purpose of cultivation of corn. There is no need for deep cultivation with its consequent root pruning, nor for any extra late cultivation of corn. The mere scraping of the surface sufficiently to kill the weeds resulted in yields equal to those obtained by deeper stirring of the soil. In ordinary seasons three cultivations to a depth of 2 to 3 inches with care to kill the weeds gave the largest net return from the corn crop with the least expenditure of labor. This appears to be in general accordance with results reported by other stations.

Certain rotations, according to the South Dakota station, permit the growth of some species of weeds while inhibiting others. General directions for keeping land free from weeds will, as a rule, not suffice and different kinds of weeds must be dealt with individually. Continuous small grain on land gives rise to increasing admixtures of wild oats, which can be practically eliminated by cutting the small grain before the wild oats develop seed. An ordinary rotation of corn, oats, and sweet clover was found to be ineffective in holding perennial peppergrass in check and may even aid in the dissemination of quack grass and the small flowered morning glory.

HORTICULTURE

Irregular bearing of the apple.—The bearing habit of apples may vary within the variety, but is in the main a variety characteristic, according to the Ohio station. The varieties tested by the station are roughly classified as follows:

(1) Annual bearers, or those varieties which have a tendency to produce

a crop each year, including Baltimore, Ben Davis, Bonum, Gano, Grimes Golden, Nottingham, Rome Beauty, San Jacinto, and Stayman Winesap. (2) Biennial bearers, or those which produce a crop one year and little or no fruit the following year, as, for example, Red Astrachan, Baldwin, Fall Jennetting, Jefferis, Loy, Oldenberg, Oliver, Wealthy, Yellow Transparent, Arkansas, Family, Summer King, Live-land, and Hubbardston. (3) Alternate bearers, or those which produce a heavy crop one year followed by a light or scattering crop the next year. In this group are Winter Banana, Boiken, Charlamoff, Early Harvest, Fallawater, Mann, Mother, Northern Spy, Rambo, Red Canada, Rhode Island Greening, Stark, White Pippin, Jonathan, King David, and McIntosh. (4) Irregular bearers, or those which may produce two or three successive crops followed by several seasons in which little or no fruit is produced. These varieties generally do not have a high average yield. The following might be placed in this group: Babbitt, Golden Russet, Greenville, Peck Pleasant, Yellow Bell-flower, Blenheim, Fameuse, Red June, Yellow Newtown, and Tompkins King.

In a study of annual and biennial bearing in York Imperial apples the Missouri station found that in the off year spur growth was short, the set was poor, and the percentage of blossom buds formed was high and independent of spur growth. In the on year spur growth was longer, a large crop set, and few blossom buds formed. "There was no correlation between the growth of the individual spur in successive years. In annual York Imperial, nonbearing spurs were longer than on alternating trees; about one-third of them formed blossom buds and the percentage of set was very high. There was a correlation coefficient of +0.45 between the growth of individual spurs in successive years. It is concluded that the biennial trees were deficient in carbohydrate the on year and in nitrogen the off year and that these deficiencies acted as limiting factors on spur performance, causing the tree to act as a unit. In annual trees these limiting factors had been removed by nitrate of soda applied the middle of September for four consecutive years, and spur performance was individual. It is suggested that supplementing spring applications of nitrogen the off year by fall applications may be helpful in establishing and maintaining annual bearing."

Fruit bud formation in apples.—In experiments at the New Hampshire station

fruit buds were formed most abundantly when the supplies of carbohydrate, water, and nitrogen were approximately balanced. When the accumulation of carbohydrates was excessive and the supplies of water and nitrogen were low, flower formation was reduced. No fruit buds were formed by bearing spurs, although they were of almost exactly the same composition as the nonbearing spurs which formed fruit buds abundantly. This was apparently due to the inhibiting effect of the rapidly growing apples on these spurs, as was the case with rapidly growing terminal buds on any shoot which inhibited the growth of lateral buds on the shaft. It was found also that developing fruit upon the spur had a tendency to restrict fruit bud formation upon an adjacent spur. This is in accordance with the long observed fact that spurs upon a tree carrying a large load of developing fruit would be much less likely to form fruit buds than those on a tree not carrying a heavy crop. Studies by the California station showed that the various deciduous fruits differentiated their fruit buds from the middle of June until the first of September under California conditions. Apparently differences in cultural treatment and environment had little or no effect on the time of fruit bud differentiation.

Bud selection in apples.—Buds selected from large productive trees as compared with buds from small unproductive apple trees made little difference in size of nursery stock, in experiments at the Maine station. There was some increase in size of the 1-year whip due to the rate of growth of the grafted bud in the spring, but little effect was observed in the case of the 2-year-old tree. The size of the seedling rootstocks had more influence on the size of the 2-year whips than on the size of 1-year-old trees. The correlation between seedling size and size of a 2-year-old nursery tree was found to be about 0.4 in four varieties.

Winter injury in apples.—Studies at the Minnesota station indicated that apple trees increase in hardiness until January, at which time maximum hardiness for the variety is reached. It remains relatively constant during the remainder of the winter. Dormancy is not a significant factor in winter injury in Minnesota, although the time of breaking dormancy is variable from season to season. The factors of greatest importance seem to be the maturity of the tree in the fall, the time at which severe temperatures occur in early winter, and the minimum temperature reached. It was found that twigs of the hardy

Duchess variety respired more carbon dioxide than did the tender Delicious variety, but responded more slowly to changes of temperature. Microscopical examination of tissue which had suffered winter injury showed that browning was localized in individual cells and that the depth of browning was a function of the number of cells killed. By evaluating this in the different parts, a numerical expression of injury was developed. Desiccation during the winter did not account for the differences in winter injury. Considerable quantities of sap were centrifuged from apple trees during the winter months, showing that free water was present in the trachea. The Montana station observed that clean cultivated orchards suffered most from winter injury, whereas those with some form of cover crop, as alfalfa, came through in good shape and made better growth accompanied by a more regular setting of fruit spurs and fruit buds.

Cover crops for apple orchards.—Measurements and records by the Washington station of tree growth in orchards that have been in cover crops for seven years or more indicate that maximum growth and vigor consistent with high yields of fruit of satisfactory quality have been attained. The growth of tree and fruit, however, continues until late in the season, so that high color and satisfactory quality are not attained until the fruit is beginning to ripen on the tree. The Montana station points out that unless the soil is exceptionally good the use of alfalfa as a permanent cover crop in orchards must be accompanied by the use of commercial fertilizers.

Orchard management.—The Iowa station has had particularly good results with apple trees grown continuously in clover sod. Trees grown on clean cultivated and cover crop soil were severely winter injured. Trees on blue grass sod for 15 years were healthy at the end of the experiment but lacked general vigor and produced low yields, on the average about 3 bushels per tree less than on clover sod. Trees with good exposure to sunlight produced 100 per cent more fruit than those under shaded conditions. There was found to be a correlation between circumference, terminal fruit buds, leaf growth, and production. Trees producing a low yield as a result of growth in blue grass sod for 10 years were completely rejuvenated by the application of 15 pounds of nitrate of soda per tree two weeks before blooming. High production was found to be generally associated with a low ratio of nitrogen to carbohydrates, and vice versa.

Nutrition of apple trees.—Seedling apple trees grew equally well in sand cultures with a considerable range of nutrient combinations, in experiments at the New York State station. Vigorous vegetative growth was secured with the nutrients in widely different proportions, provided the total concentration of nutrient ions was low. Low concentrations maintained at a constant level were conducive to best top and root development, although in some cases a concentration four times as great produced remarkably good development, provided a proper balance of ions was maintained.

Physiological changes in apple trees due to pruning.—Nitrogen was found by the Missouri station to be translocated in the spring from the older wood to the tips of the shoots. A spring application of sodium nitrate increased the nitrogen content of the tips and decreased it in the middle of 1-year-old wood. Heading increased carbohydrate consumption and thinning conserved the nitrogen and carbohydrate supplies of the tree. Heading back the leader diverted the nitrogen to unpruned laterals.

Fertilizing apple orchards.—Results of fertilizer experiments on apple orchards at the Maine station are in accord with those of similar experiments elsewhere in showing little effect from fertilization in cultivated orchards. However, two annual applications of nitrate of soda to mature Ben Davis apple trees in sod at the rate of 6 and 12 pounds per tree more than doubled the yield of fruit. Applications of phosphorus and potash seldom if ever increased yields. The greatest need for nitrogen in orchards, according to the Illinois station, appears to be in the spring, when growth begins and when the trees flower, the nitrates in the soil being especially low at this time. However, since the apple is a perennial, nitrogen applied in the summer may result in the storage of nitrogenous materials in the tree which would later be usable when needed.

Comparison by the New Hampshire station of a fertilized with an unfertilized orchard during 17 years showed that during the first 10 years the difference in yield was not significant, but after that period there was an increased yield of the fertilized trees due, evidently, to a considerable extent to the larger size of the trees produced by the fertilizer applied during the first 10 years. The total increase in production for the 17 years was not sufficient to pay the total fertilizer bill plus the compound interest for the years in which no return was received; however, the

inventory value of the trees based on their present apparent ability to remain permanent fruit producers is much greater than the present appraisal of the trees on the unfertilized plat. From this viewpoint the fertilizer has been used at a profit.

Cold storage of apples.—In the cold storage of apples it is particularly important to know the initial freezing point and the aftereffects of the freezing. The New York Cornell station found the freezing point of the fruit of 10 varieties of apples to vary from -2.85° C. (26.87° F.) to -1.02° C. (30.16° F.). The freezing point and the lethal point in apple tissue were not identical; the latter may be less than 1° C. (1.8° F.) lower than the freezing point, but in some cases there is a difference of nearly 3° C. (5.4° F.). Rapidly frozen apples showed a larger amount of discoloration than those frozen more slowly. Slightly frozen apples were usually more susceptible to *Penicillium expansum* and other fungus organisms and did not keep so well in storage as did normal fruit. The experiments indicated that -1° C. (30.2° F.) or somewhat below this point is the optimum cold-storage temperature for the apple.

Wealthy apples properly ripened and carefully handled were successfully kept in cold storage at the Iowa station until late February. The best results were obtained with fruit stored immediately after picking. Apple scald was a factor of importance only in the case of immature fruit. Soft scald was abundant in case of delayed storage of immature fruit. Highly colored apples have longer storage life, according to the Washington station, and are less subject to wilting in common storage than poorly colored fruit of the same size and date of harvest. Large sized fruits were softer and became mellow earlier in storage than small or medium sized. The station has devised a simple apparatus for testing the degree of ripeness and the condition of apples in storage.

Self-sterility of sweet cherries.—Sweet cherries are generally, if not invariably, self-sterile, a fact which accounts for failures in many orchards. The California station finds that "probably the safest way to obtain a high producing sweet cherry orchard at the present time is to plant a seedling orchard (Mazzard or Mahaleb), and later top-work the branches with scions taken from desirable strains."

Early picking of cherries.—The Oregon station found that cherries picked prematurely were undersized, low in sugar,

and high in acidity, and lost weight readily after harvest. Early-picked cherries, when canned, were small in size, dead in color, soft in texture, and flat in taste. Mature cherries showed a gain in sugar content of 10 or 11 per cent. There was no indication that cherries improved in quality after picking. Early-picked fruit tended to become more acid and bitter in storage.

Fertilizers for citrus fruits.—Expenditure for fertilizers is one of the largest items of expense in citrus culture in California, amounting to about \$60 per acre per year. The California station found that the use of fertilizers is necessary if crop production is to be maintained. Nitrogen, however, is the only fertilizing constituent, and organic matter the only other material necessary for this purpose. At least one-half of the nitrogen should be supplied in some bulky organic form, preferably in the fall. The concentrated and more quickly available forms should be applied in the spring. From 2 to 3 pounds of nitrogen per tree per year is ordinarily the most profitable amount to use.

Weekly analysis of grapefruit by the Florida station over a period of six weeks from trees receiving different sources of nitrogen gave no indication that sulphate of ammonia produced a less acid fruit, as is generally claimed by citrus growers.

Pruning grapes.—Pruning experiments at the New Jersey stations indicated that grape canes of medium length are more productive than shorter or longer canes. It was found that canes starting from wood older than 2 years were just as productive as canes starting from younger wood.

Some striking results were obtained, by the California station, by varying the amount of pruning and thinning of Muscat vines. By omitting pruning the crop was increased 279 per cent but with a lowering of quality. By thinning the blossoms of vines not pruned the crop was increased 84 per cent with an increase of 175 per cent in the average weight of the bunch and of 17 per cent in the weight of the berry.

Spray injury to peaches.—The New Jersey stations found that spray injuries appeared mainly as the leaf burning which may result in premature defoliation, as necrotic areas at the older nodes of the new growth, or as cankers on the 1-year-old wood which cause a splitting of the bark and gummosis. Atomic sulphur, flowers of sulphur, and lime, alone, caused no injury. Powdered arsenate of lead, 1.5 pounds to 50 gallons of water, alone or in combination with sulphur or lime, caused se-

vere injury. Sprays applied early in the season caused more injury than those applied later.

Core breakdown of pears.—The Oregon station found that core breakdown of pears could be controlled by picking at the proper time, without sacrifice of either yield or quality. A pressure tester devised by the station has proved to be a reliable indicator of maturity and an effective aid in controlling the trouble. The disease did not seem to be affected by the kind or length of storage.

Fertilizers for strawberries.—Nitrogen alone or in combination with phosphoric acid and potash in every instance increased the yield of strawberries, in experiments at the Michigan station. Summer application of fertilizers gave better results than spring application. The largest yields were obtained by fertilizing during both the spring and summer periods and again in the spring of the fruiting year. Nitrogen appeared to be the chief limiting element. Variations in the nitrogen content of the plant at the time of fruit bud differentiation had a greater effect on the yield of fruit than variations in carbohydrate content. Fruit-bud differentiation did not appear to depend on a particular nitrogen-carbohydrate ratio, although low nitrogen was associated with low yields and high nitrogen with high yields. However, plants with a high content of both nitrogen and carbohydrate were most productive. Purpling of the foliage in the summer or early fall indicated a deficiency of available soil nitrogen. Ammonium sulphate was more effective than sodium nitrate in increasing growth and production.

Germination of asparagus seed.—Asparagus seed under average field conditions germinates slowly. The California station found soaking the seed in water for from three to five hours at a temperature of 25 to 30° C. (77 to 86° F.) to be a practical means of greatly hastening germination.

Sex in asparagus.—In a study of the secondary sex characters in asparagus, the California station noted that in a large population there were approximately equal numbers of staminate and pistillate plants and that during the first and second seasons' growth from transplanting of the crown, staminate plants produced a greater number of stalks on each crown than did pistillate. During the first harvest season the staminate plants outyielded the pistillate throughout the entire cutting period, the difference being greatest during the early part of the season. The average number and weight of

spears from a crown were also greater from staminate than from pistillate plants, but the average weight of the individual spears from pistillate plants exceeded that of spears from staminate plants.

Growth of asparagus shoots.—The most important external factors affecting the growth of asparagus shoots are, according to the Arizona station, temperature, moisture content of the soil, and salt balance of the soil. Growth at any given temperature may be varied by changing the salt balance. The addition of sodium salts in medium or low concentration improved the salt balance. The height at which the stalk branched was controlled mainly by the temperature.

Blanching celery.—Celery can be effectively blanched by ethylene or acetylene, according to the Minnesota station, in concentrations of 1 part of gas to 1,000 of air, or lower concentrations within 6 days for the self-blanching or within 12 days for the green winter varieties. The use of acetylene for blanching, however, was not so satisfactory. Celery when treated with ethylene did not turn green again in sunlight within the usual time required for sale. In quality, texture, flavor, and color celery blanched with ethylene was equal, if not superior, to that blanched by other methods, and the keeping qualities were not impaired by the treatment. This new method of blanching seems to be of commercial value, since the gas is inexpensive and can be easily applied. The ethylene treatment did not affect either the yellow or red pigments, but acted on the green pigments, speeding up the process of etiolation, which naturally occurs when the plants are in darkness, and improving the flavor of the celery. There appeared to be also a liberation of enzymes which caused production of sugars from the digestion of starch and cell wall materials, thus improving both the flavor and texture. Blanching of some varieties was hastened apparently by infection with mosaic disease. Chlorotic varieties were more easily blanched than dark-leaved plants.

Changes in celery during storage.—Reducing sugars were found, by the New Hampshire station, to be relatively abundant in the inner leaves and petioles of celery after storage. There was an increase in the amount of reducing sugar shortly after the plants were placed in the pit, which then remained practically stationary. On the other hand, the sucrose increased steadily for some time during storage. The celery became increasingly sweeter and more

tender as the storage period advanced, due rather to the gradual increase in sucrose than to the sudden rise of reducing sugars at the outset of storage.

Acid tolerance of lettuce.—Experiments at the Michigan station showed that under some conditions lettuce is an acid-tolerant plant. Ordinary and even unusually high soil acidity per se did not prove to be detrimental to its growth. In fact, it did best in a medium of growth that was distinctly acid in reaction, when the necessary nutrient materials were present in proper quantities and proportions. The experimental evidence "leads to the belief that the very general and more or less promiscuous use of lime on lettuce soils is not only unnecessary but probably harmful."

Sterilizing greenhouse soil.—Sterilization of greenhouse soil by drenching with formaldehyde was found by the Ohio station to be effective against rosette and "drop" diseases of lettuce, but was of little value for control of wilts and nematodes of tomatoes and cucumbers. Steam sterilization either by inverted-pan, hollow-tooth harrow, or buried-tile methods while expensive was generally effective.

Varieties and strains of peas for canning.—Of the more than 500 so-called varieties of peas tested by the New York State station to determine their value for canning, many appeared to be merely "strains." Varieties which showed special promise for canning purposes were Horal, Badger, Lincoln, Richard Seddon, Duke's Delight, Chelsea Gem, Witham Wonder, Mighty Atom, and Little Marvel. It is recommended, however, that before large plantings are decided upon preliminary tests be made of the strains existing in practically all well-known varieties of canning peas.

Inoculation of canning peas.—Inoculation increases both quality and yield of peas for canning, according to experiments made by the Wisconsin station. It increases both the total yield and the percentage of the smaller sizes of peas, produces peas of a better quality and higher protein content, maintains for a longer time the best condition of the peas in the field, and increases succeeding crops grown on the land following the peas.

Alaska cannin-pea seed.—Strains of the Alaska pea which ripen in the interior of Alaska in the average season have been developed at the Fairbanks and Matanuska stations. These appear to have possibilities when purified by further selection and roguing as sources of seed for canning peas in the States.

Peas grown from the Alaska seed appear to be more vigorous than those from ordinary commercial seed.

Forcing rhubarb.—Temperature proved to be the most important factor affecting color of forced rhubarb, in experiments at the Illinois station, the lower the forcing temperature the darker red the stalks. Higher temperatures, however, produced earlier yields. Watering the roots during forcing increased the yield threefold and did not "wash out" the color of the stalks. In general, older roots produced larger yields, but 1-year-old and 2-year-old roots produced the largest net profits. A rest period, including freezing, appears to be essential to profitable forcing, 6 weeks being better than 1 or 2 weeks. A light freezing (20° F.) was sufficient to break the rest period, while a severe freezing (-10° F.) was injurious and reduced the yield. A brief, thorough freezing seemed as effective as freezing throughout the rest period.

Sex expression in spinach.—Commercial varieties of spinach are frequently mixed, of unsuitable types, or incorrectly named, according to the California station, and this highly heterozygous condition is the cause of much loss to growers and canners. Spinach is shown to be tetramorphic, producing (1) "extreme males," (2) "vegetative males," (3) monoecious plants, and (4) "female" plants. Environmental influences such as varying nutritive conditions, shading, spacing, date of planting, and mutilation appeared to have little or no effect in determining which type would develop. In general the ratio of male and female plants was 1 to 1, although some strains seemed consistently to produce a slight excess of male plants, while others of the same variety produced an excess of females. This fact, if borne out by further tests, may be utilized through plant-breeding methods to the advantage of the seed grower, who would prefer to have an excess of females in the population. Thinning appeared to be the only cultural treatment affecting the sex ratio in spinach that is likely to be of any value for the seed grower. If the seeds are sown thickly and the smaller plants are rogued out early in the season, those remaining may present an excess of females.

Fertilizing spinach.—Experiments by the New Hampshire station showed that spinach needs heavy fertilization, and that commercial fertilizers may be substituted for stable manure to a considerable extent for this purpose. Spinach receiving lime was much better than that on unlimed soil.

Storage of squashes.—Contrary to earlier recommendations, the Vermont station found that squashes kept better in a cool, dry room than in a warm, dry room. A storage temperature of 50° F. or above tends to induce heavy losses in weight, as a result of rapid destruction of carbohydrate food materials. Temperatures of 10 to 20° above freezing retard these changes and maintain the quality and palatability of the squashes through a longer period.

Setting of tomato blossoms.—The Oklahoma station found that tomato plants did not set a high percentage of fruit during the winter months when the humidity was low, and the blossoms that did set showed a high percentage of abnormally elongated styles and a dry and blackened condition of the stigma. The fruit that set very often had no seed, indicating that the failure to set fruit was due to a lack of fertilization.

Acid phosphate for early tomatoes.—The New Hampshire station found that acid phosphate prolonged the early yield of tomatoes. This is ascribed to earlier growth and production of blossom clusters rather than to hastening of the rate of ripening of individual fruits after the blossoms had set.

Hawaii sweet corn hybrid.—A promising hybrid of Henderson sweet corn and Guam corn, having the grain character of the sweet corn and the vigorous growth and leaf hopper resistance of the native sort, has been developed by the Hawaii station.

Seedling sweet potatoes.—Promising seedling varieties of sweet potatoes have been developed by the Virgin Islands station. Of 300 seedlings tested for several years, 7 have uniformly proved superior to the parent plants in every respect, and several others are promising.

Slips v. vine cuttings of sweet potatoes.—In comparative tests at the North Carolina station, larger yields of sweet potatoes were obtained with cuttings than with slips.

Relation of water level to growth of vegetables.—According to the Minnesota station, vegetables apparently differ in their response to depth of water level in the soil. In general root crops require a drier soil, i. e., deeper water level than the leaf crops. A high water level is an effective protection against light frosts, especially in case of potatoes and sweet corn.

Manure substitutes for truck crops.—Substitutes for manure in market gardening have become a necessity. The Rhode Island station, which has given the matter particular attention, reports comparisons of manure alone and of

various combinations of manure, green manures, and peat with commercial fertilizers. Replacing one-half of the manure with a complete commercial fertilizer increased the yields of early crops of cabbage, tomatoes, and lettuce over those obtained with manure alone. Peat composted with lime and commercial fertilizer gave 16 per cent larger yields of cabbage than manure alone but lower yields of tomatoes and lettuce. Practically no advantage resulted from adding stable manure to green manure at the rate of 8 tons per acre.

Almond growing.—Almond production has become an industry of considerable importance in the United States. According to recent figures, there are now approximately 100,000 acres of bearing and nonbearing trees, and extensive areas are still being planted. Over 99 per cent of the present American crop is raised in California. The almond tree is in many ways easy to grow, but it has certain special pollination, climatic, and soil requirements. All varieties tested by the California station were self-sterile; some were intersterile. In order to insure cross-pollination it is necessary therefore to interplant varieties which are not only interfertile but blossom at about the same time. A system of interplanting to secure proper pollination, as well as other cultural requirements, has been worked out by the station.

Culture of tung-oil trees.—The Florida station found that the multiple fruiting habit, or bearing more than one fruit on the terminal of an individual twig, can be transmitted by means of buds or grafts. The tendency to make a vertical growth of several feet before lateral branches were formed was corrected by the removal of a narrow strip of bark about an inch in length just above a lateral bud, when a lateral branch soon started.

Fertilizers for coffee.—Coffee responded especially to nitrogen and potash fertilizers, in experiments at the Porto Rico station. Ammonium sulphate gave better results than nitrate of soda. The best results were obtained on those plats receiving nitrogen and potash but not phosphoric acid.

FORESTRY

Cottonwood.—The cottonwood is one of the most rapid wood producers, according to the Iowa station. Plantations 35 years old on overflowed land unsuited for agricultural crops produced in lumber and cordwood an average annual return of \$10 per acre

in addition to 6 per cent compound interest on the money invested. Waste land produced in fence posts an annual profit of \$5.67 to \$7.39 an acre in addition to a like interest on the investment. Cottonwood fence posts for local farm use have been grown profitably on land valued as high as \$100 an acre. Cottonwood lumber has proved very serviceable for rough construction work in barns, sheds, and similar purposes, especially in places protected from the weather and from contact with the ground.

Eucalyptus.—The eucalyptus, which is grown more extensively in parts of California than elsewhere in this country, has been shown by the California station to have value for fuel, charcoal, insulator pins, and small turned articles, but not for lumber because of excessive checking and warping of the wood in seasoning. The blue gum makes the most rapid growth of any eucalyptus species thus far planted in California, namely, a mean annual growth of about 3 cords per acre.

DISEASES OF PLANTS

The heavy toll that disease takes of farm crops is reflected in the large number of plant disease projects carried on by the stations. The number of projects on this subject reported as active during the year was 482. Investigations on diseases of cereals and potatoes were especially numerous and active, but the work covered a wide range, as the following examples show.

Disease resistance.—Resistance as a means of controlling disease is receiving particular attention with very promising results. This has been found especially true in case of cereal diseases. The Minnesota station finds that morphology sometimes plays an important part in the resistance of varieties, and that resistance can be altered by changing the morphology of the plants by different systems of fertilization. Certain varieties and species of *Berberis* were found to be apparently resistant to *Puccinia graminis* on account of their resistance to puncture and consequent inability of the sporidial germ tubes to penetrate.

Take-all disease.—A study, by the New York Cornell station, of take-all disease of cereals and grasses (*Ophiobolus cariceti*) showed that a very large portion of the Gramineae is subject to the disease. Apparently spring planted barley and oats growing under field conditions either escape or are immune to the disease, and spring planted wheat

becomes infected only under conditions which are extremely favorable to the organism. Rye is apparently very much more resistant than wheat under greenhouse conditions. Wheat is the most susceptible of the cereals. Barley is more resistant than wheat but less resistant than rye, which is very slightly affected. Oats and rice appear to be immune. Apparently winter wheat is the only cereal likely to be seriously damaged by take-all under New York conditions. No variety of wheat tested was found to be immune to take-all, although there appeared to be marked varietal differences in susceptibility. There was apparently a direct correlation between climatic factors, such as moisture and temperature, and the amount and severity of the disease. There also appeared to be a definite relation between the hydrogen-ion concentration in the soil and the severity of the disease. Least disease was observed in plants growing in media having pH values of from 2.3 to 4.

Wheat rosette.—Wheat rosette, according to the Illinois station, is not the same as take-all due to *O. graminis*. The causative agent was not determined, but the indications were that it is a phase of a mosaic disease. The causative agent was found to be soil-borne and the disease recurred every year when susceptible varieties of winter wheat were sown on infested soil. The disease was not noted in spring wheat. It is stated that since the disease occurs in relatively few varieties it can be successfully controlled by sowing those which are resistant.

Cereal rusts.—The Minnesota station found that the urediniospores of *Puccinia graminis* germinated very quickly, the germination being stimulated somewhat by host tissue. The temperature requirements of leaf rusts seemed to be narrower than those of stem rusts. It was found that the aeciospores may begin to germinate in less than one hour at 10 to 15° C. The addition of wheat leaf tissue stimulated germination. Some spores remained viable for 19 days in a relative humidity of 80 per cent and a temperature of 12° C.

Stem rust of wheat.—The native barberry (*Berberis fendleri*) was shown by the Colorado station to be a host of stem rust. It was found that the emigration of stem rust in the absence of barberry reduced by more than two weeks previous infection dates, which, in normal years, is sufficient to allow wheat to get past the danger stage. The Nebraska station found a direct relation between the viability of the

urediniospores of stem rust and temperature and humidity. Viable spores capable of producing infection were held a year at a temperature of 5° C. and a humidity of 50 per cent.

Black point of wheat.—Seed disinfection with organic mercury compounds was found by the North Dakota station to decrease materially internal infection of wheat with black point caused by *Helminthosporium sativum*, but since the disease may come from other sources than seed, and infections of leaves, heads, and grain may occur independently of seed infection, seed treatment must be supplemented by other control measures such as seed selection, crop rotation, and resistant varieties. The life of the black-point fungus in the seed appeared to be about five years under ordinary granary conditions.

Diseases of seed corn.—Germination tests by the Illinois station of samples of corn shown at the Utility Corn Show at Urbana in January, 1925, showed certain common diseases to be quite prevalent even in the better class of seed corn. For example, infection with scutellum rot ranged from 0 to 27 per cent, averaging 5.03 per cent; *Diplodia zeae*, from 0 to 8, averaging 1.03; *Gibberella saubinetii*, from 0 to 9, averaging 1.68; *Fusarium moniliforme*, from 0 to 9, averaging 1.90; *Cephalosporium acremonium*, from 0 to 10, averaging 1.98; and dead kernels, from 0 to 14 per cent, averaging 2.20 per cent.

About 50 per cent of the seed corn used in Louisiana was found by the Louisiana station to be infected with *F. moniliforme* and about 30 per cent with *C. acremonium*, but neither of these appear to have any marked effect on the stand or yield nor on the suckering of the plant. The presence of suckers seemed to have no effect on the yield of the individual plants, although a better stand was maintained with plants that suckered freely. Better stands and consequently higher yields were obtained with corn that gave good results in the germination test, but the individual plants yielded no better than plants from corn which gave poor germination. Smooth ears gave better stands and higher yields than rough-dent ears, and the individual plants from smooth ears produced slightly larger yields.

Corn smut.—Corn smut is becoming an important limiting factor in production in certain regions, according to studies at the Kansas station. No evidence was found of systemic development of the disease in corn plants in the field. Apparently moisture is not a controlling factor, and infection does

not depend so much on the time of the season as on the stage of development of the host plant. Apparently partial control was obtained by the use of fungicidal sprays, but wherever the smut was lessened by the use of fungicides there was a corresponding reduction in yield. Planting different varieties of corn on successive dates to avoid infection gave negative results. Strains of corn showing great variations in susceptibility and resistance to smut were obtained by inbreeding.

Bacterial leaf spot of corn.—Studies of this disease by the Iowa station indicated that it is caused by an undescribed species of bacterium. The disease has a wide range of hosts, including sorghum, sudan grass, Johnson grass, foxtail and corn. Cross inoculations and cultural studies show the organism from the various hosts to be the same, although the symptoms of the disease vary somewhat with the host.

Downy mildew of foxtail.—This disease, caused by *Sclerospora graminicola*, was found by the Iowa station to be readily transmitted to corn of all types, popcorn being most susceptible. Infection took place within two days after the oospores were placed on the seed, under favorable conditions. The symptoms on foxtail and corn were markedly different in the latter, appearing as a grayish blotching and mottling, which in some cases extended throughout the whole plant, or as yellow or chlorotic areas. Many of the plants died when about 3 inches tall. Infection was readily transferred to millet, French millet, and teosinte.

Smut resistance of oats.—Of 210 varieties and strains of oats tested by the Washington station, 21 were found to be apparently immune to loose smut (*Ustilago levis*), and others more or less resistant. Among the immune varieties were Markton and Red Rustproof, the latter carrying apparently three dominant factors for immunity, any one of which prevents the production of covered smut spores. The results encourage the hope that in time this and other plant diseases may be successfully controlled by the introduction of resistant or immune varieties.

Potato scab.—Studies by the New Jersey stations indicated considerable difference between the hydrogen-ion concentration of the juices of resistant and susceptible varieties of potatoes, the latter showing much higher values, indicating that resistance may be due partly to this fact. Investigations reported by the Minnesota station indicated that abundant soil moisture during the period of early tuber formation

will retard scab infection. There appeared to be a critical period for infection in the development of the tuber. Temperature did not seem to be an important factor, but the hydrogen-ion concentration was important.

Blackleg of potatoes.—Blackleg is a widespread disease of potatoes, causing serious losses both in field and in storage. It has been studied by several of the experiment stations, notably those of Maine, Michigan, and Minnesota. Recent investigations by the Michigan station identify the causative organism as *Bacillus atrosepticus*. Losses due to the disease were found to vary with the season. Cool, wet seasons appear to be very favorable to the disease and much greater losses occur during such seasons than during warm seasons of little rainfall. No resistant commercial varieties have been found. The organism overwinters in tubers left in the ground, but not in the open soil. It quickly disappears or loses its pathogenicity in the soil. It apparently can not enter uninjured roots. Investigations by the Minnesota station showed that the pathogene and bacteria of blackleg hibernate in the pupa of the seed corn maggot and are constantly in the intestinal tract of adult flies early in the spring. Egg laying is at its height at the time potatoes are being planted. Eggs are deposited in the soil by or on potato seed pieces before and after planting, as well as in the soil around the stem of sprouting seed pieces. The eggs hatch into maggots which burrow into the seed pieces, introducing the pathogene.

Stem-end discoloration of potatoes.—The North Dakota station found that stem-end discolorations are not due entirely to the *Fusarium* wilt fungus but are also often caused by the blackleg bacterium, and both organisms may occur in the same tuber. Many discolored tubers yield no organism. The amount of discoloration due to any one cause in a year's crop is proportional to the amount of disease in the vines in the field. Of 167 discolored tubers examined 7 per cent showed discoloration to be due to *Fusarium* wilt, 22 per cent to blackleg, 2 per cent to both, 10 per cent to dry rot and other rot fungi, and 59 per cent to nonparasitic causes.

Rhizoctonia disease of potatoes.—The Washington station finds Rhizoctonia to be indigenous to western soils and to persist under cultivation as a parasite on many hosts and as a saprophyte on plant remains in the soil. It considers the disease a close second in importance to the virus diseases among the troubles of potatoes. The disease

attacks the plant at all stages. Direct injury is confined to the root system or other subterranean structures. Probably the most important injury is caused by death of feeding roots. Other crops following diseased potatoes are attacked and seriously injured by the disease because of the virulence of the parasite left in the soil. Selection of seed free from sclerotia of the disease and treatment of the seed with mercuric chloride have proved to be effective means of control.

Degeneration diseases of potatoes.—New symptoms of the various distinct degeneration diseases of potatoes previously described by the Maine station were studied with the result of showing variations in the response of the different diseases to leaf-mutilation inoculation, aphid transmission, and root and foliage contact infection. A third species of aphid, *Aphis abbreviata*, capable of transmitting mild mosaic was reported. Comparison of Long Island and Virginia seed potatoes indicated that a hot climate may cause degeneration of potatoes indirectly through favoring the spread of the disease, and emphasized the need for local or regional study of the potato degeneration problem.

Recognizing the extreme difficulty of identifying potato degeneration diseases because of their varied manifestations under different conditions, the Nebraska station among others has studied especially the environmental factors masking the disease symptoms. It was observed that light, soil moisture, and soil temperature have no effect on foliage symptoms. The effect of air temperature, however, was very pronounced and it is considered the most important factor in masking foliage symptoms.

Selecting potatoes for seed from large hills may be unsafe practice, the Vermont station points out, because hills, commonly called "giant hills," are apt to be abnormal and produce abnormal tubers. The crop grown from such seed very generally is made up of ill-formed, spindle-shaped tubers, giving evidence of disease.

Spindle-tuber disease is one of the obscure so-called virus diseases of potatoes which appears to be widespread and has been investigated by a number of experiment stations. The Nebraska station reports that it is one of the most serious potato diseases in that State, reducing the yield and lowering the market quality of the crop. It is carried over in the seed tubers and is transmitted by insects. It spreads more rapidly in irrigated lands than in

dry land fields. Environmental conditions were found to exert a marked effect on the symptoms. At high temperatures symptoms were more apparent in the plant tops and the tubers were much elongated and lighter in color, whereas at low temperatures the symptoms were less apparent. High soil moisture content tended to cause tuber elongation, and heavy soils produced more spindle tubers than lighter ones. It is stated that the best methods of control now known are "to secure a lot of potatoes containing no spindle-tuber or as little as possible, and then to select the best type tubers for planting a seed plat isolated by at least 300 feet from any other potatoes. This seed plat should be thoroughly rogued a number of times throughout the season, removing any suspicious-looking plants that might be infected."

Disease-producing viruses in potatoes.—Viruses capable of producing disease when inoculated into other solanaceous plants were derived by the Wisconsin station from apparently healthy plants of various standard varieties of potatoes. There appear to be at least two viruses present in the plant juices. These viruses were similar in nature and properties to those of other well-known virus diseases of plants with respect to filtration, dilution, insect transmission, and resistance to desiccation, putrefaction, heat, and chemicals. Inoculated into tobacco they produced characteristic diseases of three types—mottle, spot necrosis, and ring spot. Apparently potatoes are either true carriers of viruses or potato protoplasm is actually the causal agency of one or more of the virus diseases of tobacco and other solanaceous plants.

Early blight tuber rot of potatoes.—Several strains of the causative fungus of this disease have been found by the Maine station, which are distinct with respect to certain physiological characteristics but apparently alike as to virulence. While this was formerly considered a foliage disease, it was found to cause tuber rot also.

Disease-free seed potatoes.—The production of disease-free seed potatoes is rapidly becoming more difficult. The New York State station finds that high-grade seed may usually be obtained year after year by careful choice of planting stock, planting on an isolated plat, rigid inspection of the plat, and removal of all weakened or diseased plants. However, after following this method for five years the station found that stock which was practically free from leaf roll at the beginning of the

period had 15.5 per cent of that disease at the end.

Disinfection of seed potatoes.—Tests by the New Jersey stations showed both nickel and copper carbonate to be unsatisfactory for seed potato disinfection, the former preventing germination and the latter reducing both germination and yield. The use of organic mercury dust at the rate of 4 ounces per bushel gave good control. Dust treatments after the tubers were cut caused no injury to the seed pieces.

Dusts v. sprays for potatoes.—Comparative tests of dusts and sprays on potatoes at the Michigan station indicated that spraying with Bordeaux mixture, to which nicotine was added, was more effective and economical, in a season when hopperburn was very severe, than dusting with a dry copper-lime mixture containing nicotine. There was no evidence of stimulative effect of the Bordeaux mixture.

Treatment of cotton seed for disease control.—The North Carolina station found that, while the moisture content is a factor which strongly modifies the resistance of anthracnose in cotton seed to heat, drying does not kill the organism but makes conditions more favorable for the effective action of heat. Control of the diseases without serious reduction of germination was secured by drying the seed at 60 to 65° C. for 20 to 24 hours followed by 12 hours' heating at 95 to 100°. An efficient machine for applying the treatment was devised and is described.

There is no quick means of eliminating anthracnose from cotton seed under ordinary farm conditions, according to the South Carolina station. The best treatment appears to be to delint with strong sulphuric acid, place in clean bags, and store two or three years in a dry building. A certain amount of artificial heat, as in a dwelling, may be an advantage.

Cotton root rot.—Studies by the Texas station showed that in central Texas the perennial tie-vine (*Ipomoea trichocarpa*) is the most important summer and winter carrier of cotton root rot, and successful control of the disease depends upon the eradication of this weed. More than four years of clean fallow or a system of rotation using nonsusceptible crop in connection with clean cultural practices was required to completely destroy the tie-vine. The weed carriers were found to vary in different parts of the State. Growth of the fungus was completely inhibited by a 0.2 per cent normal hydrochloric acid, 0.21 per cent normal sulphuric acid, and

5.5 per cent normal sodium hydroxide, showing it to be very sensitive to acidity although quite tolerant of basic salts.

Sunflower wilt.—The Montana station isolated the organism causing sunflower wilt, and successfully inoculated it into different parts of the plant. The organism was found to be present in the soil, which becomes progressively infected.

Sunflower rust and leaf spot.—The Minnesota station found that all of the common sunflowers are susceptible to both rust and septoria leaf spot. It was impossible to control the diseases by sprays or dusts.

Tobacco black root rot.—The supposed ascospore stage, *Thielavia basicola*, of tobacco black root rot was found by the Connecticut State station to be a fungus distinct from the common conidial stage, *Thielaviopsis basicola*, the latter rather than the former being responsible for the rot.

Root rot resistant tobacco.—The Pennsylvania station found marked differences in susceptibility to root rot (*Thielavia basicola*) of different strains, hybrids, and selections of tobacco. The hybrids Olson, Hibshman, and Leaman showed superiority over common selections of Pennsylvania Seedleaf in this respect. Hibshman has proved especially successful and popular with growers in Lancaster County. Olson appears to be well adapted to conditions in Clinton County. Root rot resistant strains of both the standup and drooping types of Burley tobacco have been found by the Kentucky station, which have proved superior to the commonly grown varieties on diseased soil both in rate of growth and quality.

Black shank of tobacco.—The Florida station found the *Phytophthora* causing black shank to some extent intermediate in morphology between *P. nicotianae* and *P. parasitica*. All three forms produced similar symptoms in potato, tomato, eggplant, and castor-oil plant seedlings. All commercial types of tobacco proved highly susceptible to the organism, while *Nicotiana rustica* was resistant. The minimum temperature for infection was below 20° C. Progress has been made in the development of a resistant strain of Big Cuba tobacco.

Wildfire of tobacco.—Control of wildfire of tobacco was further studied by the Wisconsin station with the result of confirming the conclusion that control is almost entirely a matter of preventing seed bed infection. It was found that the causative organism overwinters readily in the dry and dormant condition, especially in dried tobacco leaves

and refuse and on seed. It may survive in the dormant state on seed as long as two years. Spread in the field is almost entirely dependent upon rainfall, especially when accompanied with high wind. Destruction of infective material, especially that from the curing shed, was found to be an effective means of controlling spread of the disease. The use of fungicides did not prove very effective. Evidence was obtained of the presence of a toxin produced by the wildfire organism, which, even in great dilution, is capable of rapidly producing chlorosis in plants.

Physiological drop of apples.—The Delaware station finds that in normal years, with trees producing a normal amount of compatible pollen, lack of pollination can not be considered as being the chief cause of physiological drop in fruits, as a majority of the flowers were found to be properly fertilized and embryo development had taken place in all specimens of dropped fruit. The dropping did not seem to be correlated with soil fertility.

Apple scab.—In studies on spore dissemination of *Venturia inaequalis* the Wisconsin station found that, in the vicinity of Madison, ascii were capable of discharge under favorable conditions on May 7, 1917. The maximum content of ascospores in the orchard air was observed on May 21. The most important requisite for the discharge of the ascii was the presence of an adequate supply of water. In cases where abundant ascii were in condition to eject their spores in the presence of water, heavy discharge started soon after rain began and continued with continuous rain as long as the supply of ripe ascii lasted, periods of very heavy discharge lasting from 3 to 15 hours. Conidia were found in the air only during the rain periods and particularly when rain was accompanied by strong wind. Germination tests showed that practically all naturally discharged ascospores were vigorously viable. Conidia germinated with much less regularity. "Infection from conidia applied in suspension in water was secured at will upon young leaves if fairly low temperatures (maximum at which infection occurred somewhat above 25° C.) were maintained. Old leaves were highly resistant to infection."

Adequate protection against apple scab was obtained by the New Hampshire station by spraying at the prepink, pink, and calyx stages only. Spraying with Bordeaux mixture only gave better scab control than using lime-sulphur only, but the russetting of the fruit was worse. Lime-sulphur solution satisfac-

torily replaced Bordeaux mixture, and under light scab infection a prepink and a calyx spray, or a pink and calyx spray gave adequate control.

Apple canker.—The perennial canker of apple trees, according to the Oregon station, differs from apple tree anthracnose in at least four distinct ways: (1) It is perennial in character, (2) it is more distinctly a wound parasite, (3) it has different shaped conidia, and (4) it reacts differently in culture media. The name *Gloeosporium perennans* is proposed as the scientific name and "perennial canker" as the common or horticultural name. Liberal use of Bordeaux mixture, particularly spring application of Bordeaux oil, appeared to be of some assistance in checking the disease. Eradication measures include cutting out the diseased tissues; cleaning out all wounds and injuries with an antiseptic wound dressing, preferably Bordeaux paste made up in raw linseed oil; and painting them over. The only advantage in cutting out the apple blister canker as it appears is, according to the Illinois station, to eliminate the spores of the fungus so that they will not be carried to healthy trees.

Sulphur treatment of crown gall of apples.—Sulphur treatment of soils for crown gall of apple trees in nurseries may be effective in some cases, according to the Tennessee station, but the conditions under which it is most effective have not been definitely determined.

Cherry leaf spot.—Defoliation by cherry leaf spot was found by the Michigan station to lower the vigor of the defoliated trees and to reduce seriously the yield of the succeeding year's crop. Spraying with liquid lime-sulphur diluted at the rate of 3 gallons in 100, with 2 pounds or more of lead arsenate in each 100 gallons of the diluted solution, and applied (1) just after the petals drop, (2) two weeks after petal fall, (3) four weeks after petal fall, and (4) just after harvest was found to be the most effective means of controlling the disease on sour cherries.

Citrus canker.—The organism of citrus canker changes in shape and size with age, according to the Florida station. It grew best on potato glucose agar.

Citrus blight.—A definite correlation between the occurrence of citrus blight and the soil type was observed by the Florida station. It was found to be of comparatively rare occurrence on soils with good water-holding capacity. It appears to be a physiological trouble arising chiefly from a deficiency of soil moisture during the dry season of the year, and it may also result from a sudden and prolonged excess of soil mois-

ture. No causative organism was found and no indications that the disease can be communicated by grafting. It is concluded that control should be sought through use of preventive means, such as improved cultural practices and building up the supply of organic matter in the soil.

Fig smut.—Although the fig is well adapted to a wide area in California, its culture is not so well established as that of many other fruits, because mainly of the occurrence of various forms of rotting, souring, and molding of the fruit which at times cause serious losses. One of the most serious of these troubles is, according to the California station, so-called smut due to *Aspergillus niger* which is carried into the figs by insects, especially the dried fruit beetle (*Carpophilus hemipterus*). Destruction of the insects appears to be the most promising means of control. The best methods at present known for accomplishing this consists in destroying all old fruit, fruit culls, and refuse in which insects breed. Spraying and soil fertilization were of no avail. The Black Mission and Kadota varieties were found to be much less affected by smut and similar troubles than the Calimyrna and Adriatic sorts, because their solid structure and closed eye exclude insects from the inside of the fruit.

Fig rot.—A rot of the Smyrna fig, doing much damage in California, is reported by the station to be due to a fungus tentatively identified as *Oospora verticilliodes*. The fact that the trouble was found to occur only in caprifried figs is taken to indicate that the source of infection is *Blastophaga*.

Black rot of grapes.—The primary point of new infection of black rot of grapes is, according to the Delaware station, in lesions on the first few internodes of the cane and not in leaves and rotten fruit as has previously been stated. Black rot can not be controlled unless spraying is started much earlier than is commonly recommended. The station found that the so-called "carry-over" lesions in grapes contain several diseases other than black rot. Anthracnose (*Sphaeloma ampelinum*) and bitter rot (*Melanconium fuligineum*) were found carrying over in the first few internodes of the canes. Evidence was also found of the occurrence of Reddick's dead arm disease (*Cryptosporrella viticola*) and also of *Pestalozzia uricola*, a European grape rot, in carry-over lesions on the canes.

Root rot of grapes.—A mushroom root rot of grapes, prevalent in the Ozark region, was found by the Missouri sta-

tion to be due to *Clitocybe tabescens*. The disease is associated with lands which formerly were covered by hardwood timber, especially oak. It appears to be practically unknown in strictly prairie soils and in old land, except at the margins in close proximity to timbered lands. It attacks grapevines and fruit trees chiefly in places where the soil is poorly drained. Drainage is therefore considered the most important remedial measure.

Pear blight.—Pear blight is, according to the Oregon station, probably the most destructive disease of fruit trees in America, attacking blossoms, shoots, large branches, trunks, and roots. The best varieties of pears are susceptible to the disease. The most successful method of combating the disease yet suggested, viz., to cut out promptly all the affected parts and disinfect the wounds, merely reduces the losses; it does not entirely prevent them. Of numerous varieties and species tested by the station, only *Pyrus ussuriensis* showed resistance in the young shoot and *P. calleryana* in the trunks and roots. The first is of little or no value on account of its slow growth. The latter appears promising as a rootstock. It is suggested that "losses from trunk and root blight can be largely prevented in the newer orchards by planting a resistant variety like Old Home on a resistant rootstock like *P. calleryana* or Ba Li Hsiang and topworking them when 3 or 4 years old with the desired commercial variety."

Chlorosis of pineapples and other plants.—Manganese chlorosis of pineapples, a trouble which at one time seriously menaced the pineapple industry of Hawaii, was found by the Hawaii station to be due to the depressing effect of manganese, which occurs in unusual quantity in many Hawaiian soils, on the assimilation of iron. It was shown that the trouble can be overcome by spraying the plants with a solution of iron salts. The treatment is now in general use in over half of the pineapple fields of Hawaii. The Rhode Island station found evidence that chlorosis sometimes following heavy liming in that State is due to need for manganese. Chlorosis of spinach, oats, beets, beans, and peppers was reduced or prevented by applications of soluble salts of manganese. Direct correlations were found between the soluble manganese content of the plants and both manganese applications and the correction of chlorosis.

Raspberry anthracnose.—Anthracnose of the raspberry was controlled by two seasonal applications of lime-sulphur, in experiments at the Illinois station.

Two sprays, one a delayed dormant application as the leaflets were opening and the other a pre-bloom spray applied a week before the bloom, were effective. The addition of a casein-lime preparation gave somewhat better control. In experiments at the New Jersey stations the disease was controlled by four applications of lime-sulphur which gave better results than Bordeaux mixture. The addition of calcium caseinate to lime-sulphur increased its fungicidal value.

Virus diseases of the raspberry.—The Michigan station reports at least five raspberry diseases of the virus type in the State. Two species of aphids, *Amphorophora rubi* and *Aphis rubiphila*, were found to be transmitting agents. Roguing out diseased plants was effective with some of the troubles but of doubtful value with others. The rate of spread of raspberry mosaic, under the same climatic conditions, was found by the New York State station to vary greatly according to the variety. The rate of spread also varied in different sections of the State, due probably to the relative abundance of aphid carriers. Roguing as a means of control has yielded excellent results.

Yellows-resistant cabbage.—Continuing work in selecting yellows-resistant second-early varieties of cabbage, the Wisconsin station found that desirable resistant types may be obtained from any of the standard varieties. Selections of All Head Early and Glory-Copenhagen types are approaching a stage where they will be of commercial value.

Wire stem of cabbage.—Wire stem due to *Corticium vagum*, which is the cause of widespread and serious losses, has been exhaustively studied by the New York Cornell station, which finds that the strain of the organism causing the disease is physiologically distinct from that causing lesions in potato stems. "The minimum and maximum temperature for the growth of the fungus in pure culture are approximately 9 and 31° C. The optimum is not sharply defined, but it lies between 22 and 26°. The fungus exhibits a wide pH range for growth, the minimum being approximately 2 and the maximum above 10.4. The optimum is about 6.2. Practically any combination of soil temperatures and moistures favorable for the growth of the host is favorable for the growth of the fungus and for the development of wire stem. Consequently, no changes in the environmental conditions will control the disease."

Composition of diseased celery leaves.—Celery leaves affected with *Cercospora apii* and *Septoria apii* were found by

the Michigan and New Hampshire stations to contain less nitrogen than healthy leaves. The nitrogenous compounds of the diseased leaves contained more ammonia, humin, and protein and less hydrolyzable matter, acid amide, and basic and nonprotein nitrogen than healthy leaves. Nitrites were found to be present in the diseased leaves.

Downy mildew of cucumbers.—Spraying and dusting experiments by the Florida station showed that fungicides which contained copper were superior to those not containing it. Fungicides applied in the form of dust gave almost as good control as did liquid sprays. The cost of the dust, however, when both material and labor were considered, was about twice the cost of the liquid spray.

Toxins in onion juice.—Toxins of two general kinds, volatile and nonvolatile, were found in onion juice by the Wisconsin station, cooperating with the Department of Agriculture. The former decreased in storage and sprouting. Experiments with various onion bulb parasites showed in general that the reaction of each fungus followed the same trend with the dissolved as with the volatile toxins, and indicated that the host toxins may be one of the numerous factors which determine the degree of parasitism attained by a given parasite.

Onion smut immunity.—Of 39 species of Allium tested by the Massachusetts station 8 seemed to be immune to onion smut (*Urocystis cepulae*) and 31 showed varying degrees of susceptibility. Thirteen species appeared to be very susceptible, and in the same class as the common onion, of which 54 varieties were examined without finding evidence of any considerable resistance to smut.

Root rot of peas.—*Aphanomyces euteiches* was found by the New Jersey stations to be the causative organism of one of the major root rots of peas in the State, pure culture inoculations producing the typical symptoms. The zoospores remained active in water for five to seven days and were capable of causing infection at any time during this period; but there was little migration of the zoospores in the soil, tests showing that they were unable to traverse a distance of one-half inch, and there was very little spread of the disease in the field. A soil moisture content of 30 per cent saturation was found to be close to the minimum for infestation, higher percentages of soil moisture being more favorable. Of a large number of legumes inoculated with this organism, garden and Canada field peas were found to be very susceptible and hairy vetch slightly so. Other leg-

umes tested as well as corn were not attacked.

Sweet-potato scurf.—Tests by the New Jersey stations showed that applications of from 300 to 600 pounds of sulphur per acre were effective in reducing scurf infection. In one test the disease was almost completely controlled by the use of about 600 pounds per acre, although the yield was reduced about 16 bushels. The production on untreated plats and those receiving 300 pounds of sulphur was practically the same. The results showed the beneficial effects of sulphur in reducing the disease in light soils. The fungus causing scurf was found to spread gradually on the stem of the plant. Early harvesting on severely infected areas reduced the number of black stained potatoes. Inoculation tests showed that infection will not take place in presence of high acidity, the point of infection being somewhere between pH 4.5 and 5.

Sweet-potato pox.—In studies by the New Jersey stations on the relation of soil moisture to this disease it was found that with from 4 to 6 per cent moisture, based on the water-holding capacity of the soil, the potatoes and roots were severely poxed, and on most of the plants the roots were completely blackened. With from 8 to 10 per cent moisture the potatoes were not attacked, but the roots showed many pox spots. With from 12 to 16 per cent moisture the infection was very slight, and with 18 per cent, which was the water-holding capacity of the soil, there was no infection of the roots. The results showed the importance of maintaining a favorable soil-moisture content, especially during June and July when the most severe attacks occur. The application of from 200 to 300 pounds of sulphur per acre annually was sufficient to control the disease. The causative organism was not obtained in pure culture.

Nailhead rust of tomatoes.—The Florida station found that copper sprays and dusts were superior to those not containing copper for the control of nailhead rust of tomatoes. Homemade Bordeaux mixture, made either with rock or hydrated lime, gave the best control. Some commercial copper sprays recently put on the market proved to be of no value. In a varietal resistance trial the Globe proved to be the most resistant.

Tomato wilt.—The Kansas station found the most practicable effective method of controlling tomato wilt, due to *Fusarium lycopersici*, to be the growing of resistant varieties. "Six varie-

ties introduced into the State for trial purposes and one developed at the station have proved wilt resistant, commercially desirable, and climatically adapted to Kansas. They are Louisiana Red, Louisiana Pink, Marvel, Norton, Norduke, Marvana, and Kanora."

Disinfection of tomato and pepper seed.—Seeds of tomato and pepper were treated with commercial disinfectants for periods varying from 5 to 25 minutes, in experiments at the Florida station. Five minutes' treatment reduced the germination of the seed, the injury being increased as the time was lengthened. With 25 minutes' treatment the amount of injury was 15 per cent. Ten minutes was found sufficient for disinfection, and this is advised, allowing for a 10 per cent injury. The treatment was found to kill the weaker seed and eliminate the weaker plants in the seed bed, thus proving beneficial.

Pecan scab.—The organism of pecan scab, *Fusicladium effusum*, was found by the Florida station to grow best at 25° C. and slower at 15 and 30°. Inoculations took from 5 to 21 days to show symptoms. The disease was found to be carried over in the old husks and twigs, and infection in the groves always became worse after rains.

Coconut bud rot.—Coconut bud rot has been found by the Porto Rico station to be associated with a species of *Phytophthora*. The period of incubation may vary from two to nine months, depending upon weather and other conditions. Attempts to transmit the disease through diseased roots gave negative results.

Fusarium disease of vanilla.—Fusarium disease of vanilla was found by the Porto Rico station to spread rapidly through the soil and quickly attack and kill aerial roots of vanilla plants. No wilting was observed as in the case of banana wilt caused by *F. cubense*.

Phytophthora disease of tulips.—A hitherto unreported tulip disease due to *P. cactorum* was found by the Illinois station to be common in moist, ill-ventilated situations. It was more common on double than on single blossoms. The iris was also found to be susceptible to inoculation of the disease. The only suggestion made as to prevention is to avoid situations that are especially humid.

Taxonomy of Fusarium.—The fundamentals of taxonomic studies and classification of Fusarium, with special reference to the identification of species, were defined and formulated in a report published during the year by the plant pathologist of the Tennessee station cooperating with other specialists.

Color pigments in Fusaria.—Hydrogen-ion concentration of the culture media controls the development and determines the color of pigment in Fusaria, according to investigations reported by the California station. The pigments produced were of two kinds, diffusible and nondiffusible; that is, pigment retained within the cell and pigment escaping through the plasmatic membrane and cell wall. Pigments were produced by practically all of the species experimented with in dextrose solutions at hydrogen-ion concentrations between pH 3.5 and 5.5.

Physiologic forms of *Helminthosporium*.—At least 37 physiologic forms of *Helminthosporium* have been found by the Minnesota station. Some of these mutate readily in culture media, the mutants differing considerably from the parents both morphologically and physiologically, and varying in virulence. The organism lives in the soil year after year, the spores being very resistant. They germinate readily only in the presence of certain plant tissues. Cereals proved to be more susceptible when somewhat weakened; consequently good cultural practices aid in reducing losses. *H. gramineum* was found to be severe on barley, especially the early sowings, because soil temperatures of from 10 to 12° C. are most favorable for infection.

Liquid v. dust sprays.—The relative value of liquid and dust treatments has been the subject of much investigation by the stations, with somewhat discordant conclusions. The New York State station, comparing liquid Bordeaux mixture with copper-lime dust of practically the same composition as the liquid spray on potatoes, found that in seasons when blight and leafhoppers were both fairly abundant the Bordeaux spray gave far more satisfactory control than the copper-lime dust, even when the dust was used twice as often as the spray, and concludes that for maximum yields, and probably for maximum net profits, spraying should be given the preference over dusting if adequate facilities for spraying are available.

ENTOMOLOGY

Alfalfa weevil.—Charting the climatic conditions affecting the distribution of the alfalfa weevil (*Phytonomus posticus*) in the United States, the Montana station found the areas of optimum and limiting conditions to agree in all essential particulars with the present progress of infestation. The station concludes that it is "highly probable that the alfalfa weevil has been imported into this country many times and

that it also has often been shipped out of the quarantine areas into other parts of the country, but that it has failed to establish itself except where it was placed in a region of favorable climatic conditions." Two limiting factors are temperature, applying largely to the hibernating adults, and humidity, which applies to the larva and its fungus enemies. The Idaho station found that the activity and control of the alfalfa weevil is affected to a significant extent by seasonal variations. In the late, cold spring of 1923, with excessive moisture in May and June, early maturity was retarded, but the period and extent of injury was increased. In 1924 conditions favored early maturity and an extremely short feeding period.

The alfalfa weevil has become one of the most destructive and important insect pests in Nevada, but the Nevada station finds that it can be controlled by spraying with arsenical poison applied just as the alfalfa begins to look grayish. Spraying was found to be more effective than dusting. The introduced parasite, *Bathyplectes curculionis*, has become common throughout the weevil infested territory and often kills the majority of the weevil larvae.

European corn borer.—The New Hampshire station found that under New Hampshire conditions about 60 per cent of the borers exhibit two generations, but only a small percentage of the second generation is able to overwinter successfully, and the survivors develop into adults of small size capable of producing a relatively small number of eggs. Apparently this is a limiting factor in relation to normal increase of this species under field conditions.

Cornstalk borer.—The New Hampshire station noted that in the early stages the larvae of this insect appear to prefer the grasses. There may be from seven to nine instars. Twenty-two different host plants have been observed under field conditions. Some females are able to deposit eggs one day after emergence. Some parasites were found.

Cotton-boll weevil.—Boll weevil injury appears to be a variable factor in cotton production in the Piedmont region of South Carolina. For this reason the South Carolina station finds that early application of poisons may not be profitable in some seasons. In normal seasons the main reliance should be placed upon late applications. Usually these applications should be started as soon as boll-weevil injury is observed on as many as 10 per cent of the squares of the plant. The Florida stripping method did not give

profitable results under the conditions of the South Carolina experiments.

Dusting with calcium arsenate did not give satisfactory control of the boll weevil in Oklahoma. The molasses arsenate treatment gave better results. Use of the Florida method resulted in a loss. The use of a cage in which punctured squares and forms are placed and which allow the parasites but not the weevils to escape is recommended, as is complete final picking of cotton as early in the fall as possible and the immediate destruction of the plants unless they have already been killed by frost.

The cotton hopper.—Further studies by the Texas station of the cotton hopper (*Psallus seriatulus*) showed it to be a large factor in producing the blasting of small cotton squares. Eggs were found on the tender growth of the cotton plant, on five species of *Croton* and on two of *Monarda*, and also on remnants of cotton stalks which were broken up and plowed under during the winter and brought to the surface by cultural operations in the spring. There was no migration from *Croton* weeds to cotton. Overwintered eggs first begin to hatch about April 1 and hatching continued until the middle of May. The maximum number of eggs, which were laid singly, during the life of a pair was 34. The average egg stage was 7.8 days, and there were five instars. In summer complete development from hatching to the adult stage required from 7 to 10 days. Good control was obtained with sprays containing sulphur.

Leafhoppers and curly leaf of sugar beets.—Sugar beets are subject to severe damage as a result of insect attack. The Utah station records a list of 12 or more insects preying upon this crop. One of these, the leafhopper or white fly, is responsible for transmission of the very destructive curly leaf disease, which has resulted in the abandonment or removal of sugar factories in California, Idaho, and Oregon. The loss to farmers in the Bear River Valley in 1924 is reported to have been \$1,500,000.

Wheat stem maggot.—The wheat stem maggot (*Meromyza americana*) is, according to the South Dakota station, widely distributed in that State wherever certain native grasses or cultivated cereals are found. The station found that the adult flies appear about the first of June and that there may be three generations a year, although in some cases only two generations are produced. The maggot was found to be heavily parasitized, but parasites apparently can not be relied upon to control the

pest. Such control measures as rotation of trap crops, destruction of volunteer grains and grasses, and late planting of fall grain are recommended.

Field cricket.—A study of the natural enemies of the field cricket by the South Dakota station showed these to include 2 hymenopterous egg parasites, 2 species of nematode worms, 1 species of gregarine, 1 Tachnid fly, and several mites, all attacking the nymphs or adult crickets, which are also attacked by several predacious animals, but these are not sufficient to hold the crickets within bounds. The most satisfactory means of control was destruction of the eggs by disturbing the soil in which they are laid during the late summer and fall. An exposure of one-half hour killed the eggs. Poison bait gave a maximum kill of only 50 per cent.

Cyanide for grasshoppers.—Two hundred pounds of granular calcium cyanide per acre, distributed over the ground where young grasshoppers congregated, gave a 100 per cent kill in tests made by the Washington station. It gave best results when applied in the evening or during cool, cloudy days.

Codling moth.—The New Jersey stations found that the amount of injury done to the apple by the codling moth under arsenical treatment varies, within limits, inversely as the quantity of arsenic applied per tree per treatment, inversely as the constancy with which the coating is maintained during the periods of larval entry, and directly with the concentration or density of the codling moth infestation, the concentration being the most powerful factor. Dust treatments were less effective and somewhat more expensive than liquid treatments.

The first brood of the codling moth is by far the most important in commercial apple growing, according to the Virginia station. Failure to control the first brood is normally followed by continuous egg laying and hatching from late June or early July to late September. Timely and thorough spraying is therefore necessary. In orchards where large numbers of worms winter or where the proportion of wormy apples at picking time amounts to about 5 per cent of the crop, four lead arsenate sprays are recommended as follows: (1) When most of the petals have fallen; (2) about 3 weeks after petal-fall stage; (3) about 5 weeks after the petal-fall stage; and (4) about 10 to 11 weeks after the petal-fall stage.

Oil emulsion for San Jose scale.—Home-made lubricating oil emulsion proved, in experiments by the New York State station, to be an efficient insecticide

for the control of San Jose scale and was successfully used to combat this pest in old apple orchards where it had been difficult to secure satisfactory protection with lime-sulphur solution of standard strengths.

Rosy apple aphid.—Delayed dormant applications of dust mixtures containing nicotine did not give satisfactory control of the rosy apple aphid, in experiments at the New York State station, but were effective if used not much later than when the pink color of the more advanced blossom clusters was first observed. In addition to sufficient dosage, other favoring conditions were fairly high temperatures, freedom from foliage moisture, and little or no air stirring. Applications of dust mixtures during the pink period and calyx period invariably proved ineffective.

Fruit-tree leaf roller.—The Pennsylvania station found that the habits of the red-banded leaf roller (*Eulia velutinana*) differed widely from those of the so-called fruit tree leaf roller of more northerly apple growing regions, and that the recommendations for the control of the latter were not applicable in Pennsylvania. In a study of the life history, habits, and control of the red-banded leaf roller, three complete generations in a season were recorded. A number of parasites were reared from the pupae. Arsenate of lead applied at the pink stage at the end of June or early in July and at the end of August or beginning of September poisoned the young larvae of the first, second, and third generations, respectively, and prevented injury to the foliage and fruit.

Methods of control of the fruit-tree leaf roller by use of oil emulsion sprays were worked out by the Idaho station and successfully applied in practice. Lubricating oils proved but little more effective and were more expensive than neutral oils for this purpose. The emulsion spray controlled San Jose scale as well as roller.

The most promising means of controlling the fruit-tree leaf roller found by the New York State station was the application of oil preparations at the period when the eggs were about ready to hatch and treatment of the trees with arsenicals when the young caterpillars first appeared, followed by applications at intervals of a week or 10 days throughout the hatching period. No appreciable improvement in the killing efficiency of common spray mixtures resulted from the incorporation of spreaders, such as glue, calcium caseinate, or soaps.

Oyster-shell scale.—The New York Cornell station concludes that there are

two distinct forms of the oyster-shell scale, one occurring especially on the apple, the other on the lilac, the one on the apple being probably the older. The evidence is not sufficient to determine whether the differences are great enough to warrant the erection of a new species or only of a new variety from the form on lilac.

Green citrus aphid.—The Florida station found that from five to seven days are required to complete the nymphal stage of the green citrus aphid. Adult females produced on an average of five young per day. The most important hosts, in addition to citrus, proved to be pears, Mexican tea (*Chenopodium ambrosoides*), fireweed (*Erechtites hieracifolia*), and cudweed (*Gnaphalium*). A predator, the blood red lady beetle (*Cycloneda sanguinea*), was found to eat on an average 16 aphids per day. A number of other species of lady beetle were observed eating the aphids, and syrphus flies were also predators. These predators, however, were not very efficient in controlling outbreaks when conditions were favorable for rapid aphid multiplication. Lime-sulphur and the oil emulsions were effective, especially with a 1 to 800 addition of nicotine sulphate. Dusting with 3 per cent nicotine sulphate-lime dusts was effective in a quiet atmosphere or under tents. Dipping affected twigs in a solution of soap and tobacco was effective on young trees early in the season.

Plant bugs on citrus.—In experiments by the Florida station a trap crop of *Crotalaria* gave almost perfect control of plant bugs in a citrus grove, provided there were green pods on the *Crotalaria*.

Control of cranberry insects.—The New Jersey stations found that the cranberry girdler (*Crambus hortuellus*) could be killed by September flooding without serious damage to the crop of that or succeeding years. This flooding also controlled the blossom worm (*Eniglaea apiana*). Keeping a coating of lead arsenate on the cranberry vines from July 1 to September 1 not only did not injure the vines but gave a 10 per cent increase in yield, perhaps due to the destruction of some obscure cranberry feeders. Application of a mixture of arsenate of lead and resin fish oil soap burnt the foliage, but lead arsenate alone did not.

Dusting versus spraying for grape rootworm.—Dusting did not prove as effective as spraying for the grape rootworm, in experiments at the New York State station. In view of these results and until more efficient dust preparations which will stick to grape foliage have been found, grape growers are urged to

use homemade Bordeaux mixture with lead arsenate.

Control of oriental peach moth.—The Connecticut State station obtained some reduction of injury by the oriental peach moth by spraying with nicotine solution in June to kill the eggs and by dusting with lead-arsenate-sulphur dust. Calcium fluosilicate compound and sulphur-lead-arsenate dust had considerable effect in preventing entrance of newly hatched larvae into the fruit. Bait pans containing molasses and yeast caught large numbers of moths.

A serious outbreak of the oriental peach moth in New Jersey in the summer of 1923 led to a special State appropriation to the New Jersey stations for study of the insect with a view to finding effective means of control. There were found to be three full generations and a partial fourth in the region of New Brunswick, that is, a portion of the larvae of the third brood remained in their cocoons for the winter and did not change into pupae and emerge as adults in 1924. Fall applications of paradichlorobenzene were found to be effective in killing the larvae of the insect cocooned on the trunks of the trees at or near the surface of the ground. Cultivation in April, at least 4 inches deep, killed 100 per cent of the overwintered larvae and pupae on the ground above the trees. Forty per cent nicotine spray was also effectively used.

Control of pear psylla.—In experiments at the New York State station, lime-sulphur showed decided ovicidal properties in case of the pear psylla. Spray mixtures gave better control of the nymphs than dust mixtures, lime-Bordeaux mixture containing nicotine being best. For control of te hadults a calcium cyanide dust or a 2 per cent nicotine-lime dust was effective.

Plum aphid.—Studies by the California station of the life history of the mealy plum aphid indicated that in most instances the insect does not winter in the egg stage on prunes and plums but migrates from tules and reed grasses to the orchards in the spring and back again in the fall. Soap sprays gave best general control when thoroughly applied.

The strawberry root louse.—The strawberry root louse (*Aphis forbesi*) is widespread, although not highly injurious in Tennessee, according to the Tennessee station. It passes the winter in the egg stage in the pedicels of the plants, beginning to hatch about February 15. It is rarely found on the roots. Increasing the daily light exposure delayed the

appearance of the true sexes and prolonged the period of viviparous reproduction. "It is possible that a combination of long days and a temperature of 50° F. or higher might have sufficed to keep the sexes from appearing."

Among the more important natural enemies noted were a small syrphid (*Paragus tibialis*), a Braconidae (*Diaeretus fuscicornis*), and several Coccinellidae and Chrysopidae.

Low temperature control of bean weevil.—Temperatures below -10° C. for a period of 12 hours proved fatal to all stages of the bean weevil (*Bruchus obtectus*), in experiments reported by the Minnesota station. The growth of the insect in beans was shown to be materially retarded by storage in temperatures even as high as 64° F. The capacity of the weevil to resist low temperature was found to be limited by the length of time it could remain in the supercooled condition. This varied with the stage, active adults being least resistant and eggs most resistant. The electrothermal method did not give the true freezing point because of radiation and injury of the insect. A modification of the method which did not involve injury was devised and tested.

Generation of the pea aphid.—Nineteen generations of the pea aphid were raised during one year by the Kansas station with peas as the host plant and 21 generations on alfalfa. The age of the female when the first young were produced was 8.3 days on alfalfa and 8.9 days on peas. The length of the reproduction period was 10.8 days on alfalfa and 5.4 days on peas. The total number of young produced was 41 on alfalfa and 19.7 on peas, and the length of life on alfalfa was 21.3 days and on peas 14.5 days. In the fields the aphids were found to reproduce rapidly in March. They became scarce in early June and remained so during the summer until September.

Striped cucumber beetle.—Two generations of this beetle occur in Iowa, according to the Iowa station. A few adults were found beneath rubbish in April, evidently having wintered over in this stage. Overwintering females were found to deposit on an average 230 eggs and the adults of the summer generation began to emerge July 17, the females of this generation depositing an average of 327 eggs. Gypsum-calcium-arsenate dust gave the most satisfactory control, the first application being made when the seedlings started to break through the soil. From 8 to 12 dustings during the season were necessary.

Control of the squash-vine borer.—Neither calcium cyanide nor trap crops proved, in experiments at the West Virginia station, so satisfactory as the combined nicotine-lead-arsenate spray in controlling this insect.

Cyanide for nematodes.—Satisfactory results in the control of nematodes were obtained by the California station with calcium cyanide drilled in the furrows as the ground was plowed, at the rate of 600 pounds and upward per acre. The cyanide had a marked stimulating effect on tomatoes grown on treated soil.

Pale western cutworm.—The Montana station found that 90 per cent of the eggs of the pale western cutworm were laid upon stubble fields just cut, and on these the worms were very abundant in the spring. If such fields were plowed in the spring and planted to grain the crop was practically destroyed, but if the land was summer fallowed 75 per cent of the worms were destroyed. The worms were observed to feed on rabbit brush, Russian thistle, and goldenrod before laying eggs.

Coconut scale control.—Active measures to control the coconut scale, a severe outbreak of which had occurred on the island, were taken by the Guam station and the island authorities. Cleaning up and spraying gave good results, but natural enemies appear to offer the most promising means of control. Three important natural enemies have been found in the island, the most promising being a black ladybird, *Cryptognonus orbiculus nigripennis*, and others are being introduced.

Mealy bug on catalpa.—The mealy bug (*Pseudococcus comstocki*) is reported by the Virginia station to be a serious pest of the umbrella catalpa, marring its appearance and weakening its vitality and growth. Most of the injury is done by the third generation in late August and September. Pruning back severely, thoroughly cleaning the trees and burning the rubbish, and spraying with lime-sulphur or oil spray in the dormant season are suggested as means of control.

Spruce budworm on jack pine.—This insect although morphologically indistinguishable from the budworm on spruce and fir appears to be a distinct biologic species, according to the Minnesota station. In the region of infested jack pine the spruce and fir are not affected, and in the regions where spruce and balsam have been destroyed the adjacent jack pine stands are not infested.

Leaf-mining Diptera.—A monograph with extensive bibliography on the leaf-

mining Diptera of North America, representing an exhaustive study of the group, was issued by the New York Cornell station during the year. This bibliography brings together for the first time many scattered notes on the various species of dipterous leaf miners and summarizes the work of several years in both field and laboratory on their life histories and habits. The economic importance of the leaf miners is recognized chiefly by such forms as the beet leaf miner, the chrysanthemum leaf miner, and the box elder leaf miner. The Diptera are represented by 6 leaf-mining families and 11 leaf-mining genera in North America, and a number of these genera are entirely of the mining habit.

Control of the boxwood leaf miner.—Experiments by the Maryland station showed that the boxwood leaf miner can be controlled cheaply and effectively by spraying with a stock food molasses diluted 1 to 4 parts of water with the addition of nicotine sulphate at the rate of 1 part to 500 or 600 parts of the diluted spray material. The value of the spray was increased by covering the sprayed plants during rains with muslin or canvas.

Nicotine carriers.—The efficiency of nicotine insecticides was found by the New Jersey stations to be increased by mixing them with carriers made up of 25 per cent finely ground dolomite and 75 per cent hydrated lime. In such carriers there is a rapid volatilization of nicotine at 70° F.

Chloropicrin as an insecticide.—Chloropicrin alone or in combination with carbon tetrachloride was found by the Minnesota station to be very effective in fumigating upholstered furniture infested with insect pests. Chloropicrin and carbon tetrachloride were used as a localized fumigant in flour mills with very good success. Houses newly infested with clothes moths and black carpet beetles were freed of such pests by one treatment with chloropicrin and carbon tetrachloride.

Spreaders.—No definite proportional relationship was established between the surface tension values of spreader solutions and the observed spreading properties of the different substances, in experiments reported by the Oregon station. "Of the materials tried, water-soluble protein substances gave best spreading at lowest concentration for the greatest number of surfaces tested. Skim milk, neutralized with hydrated lime, and certain other milk products appear to be the best material for practical purposes. The concentration of a spreader solution that will give best

results depends upon a number of variable factors, such as the type and age of the surface to be sprayed, the force used, and climatic conditions. The amount of lead arsenate that adheres to the leaf surface is approximately the same when a spreader is added as when one is not."

Fluosilicate as an insecticide.—Sodium fluosilicate has been found by the Tennessee station to have certain advantages over arsenicals as an insecticide, namely, it is cheaper, it acts as a contact as well as stomach poison, it kills more rapidly, it is not poisonous to human beings, and it is effective against a wide range of insects, such as chicken lice, roaches, potato beetles, Mexican bean beetle, and striped cucumber beetle. It has the disadvantage of having a very high density, 30 cubic inches to the pound, whereas the best results in dusting are obtained with materials having a volume of 80 cubic inches to the pound. It is obtained in quantity as a by-product in the manufacture of acid phosphate and promises to be a competitor of the arsenicals. The foliage injury is negligible if the material is mixed with lime and used as a dust.

Blister beetles attacking various farm or garden crops may, according to the Arkansas station, be killed by dusting with a mixture of equal parts of sodium fluosilicate and hydrated lime, or with calcium fluosilicate. Since the beetles usually feed in swarms, it is easy to cover a large number of them with a relatively small quantity of the insecticide. Sodium fluosilicate mixed with an equal quantity of hydrated lime and calcium fluosilicate may be applied with safety to tomatoes, potatoes, soy beans, and alfalfa.

Oil sprays.—The Washington station found no important difference in the killing rate of oils of similar boiling range from petroleum stock of asphalt and paraffin bases. The middle of the lubricating oil fraction seemed to be the most effective. The viscosity of an oil appeared to have only an incidental relation to its insecticidal effect and therefore little benefit is to be expected from the addition of kerosene to a lubricating oil.

Xanthates as soil fumigants.—The California station found that xanthates may be used alone as a soil fumigant, but are most effective in an acid medium in which they are converted into xanthic acid, which decomposes in alcohol and carbon bisulphide. The rate of decomposition can be regulated by adding in full or in part the amount of acid salts necessary to neutralize the alkaline

base of the xanthate. This makes possible a quick fumigating action when first applied and a slow subsequent release of carbon bisulphide, which is desirable for insects or nematodes that may be present in a resistant stage when the first application is made. Calcium phosphate and sulphur were found especially valuable for the neutralization of the xanthate.

APICULTURE

Queen bees.—Observations by the Texas station indicated that the earliest stage at which queens begin the laying of eggs is 4 days and the latest 18 days, the normal being 10.9 days. This indicates that if the queen is not laying on the eleventh day she should be replaced. The value of wholesale requeening every year was indicated.

Sirup for winter feeding of bees.—By the use of commercial invertase the Minnesota station found it feasible to invert sucrose solutions of concentrations up to 75 per cent, the sirup being superior to ordinary sucrose sirup for feeding bees in the fall, having the same concentration as honey, whereas sucrose sirup is more dilute. It is also more wholesome to the bees than sucrose.

Brood rearing of bees.—The peak of brood rearing was found by the Kansas station to occur about the first week of May, with a possible second peak later if the colony is plentifully supplied with food and the temperature is favorable. There was an inverse correlation between the rate of brood rearing and the honey flow. Brood rearing was found to begin and end in response to a temperature stimulus. A direct correlation was found between the supply of food and the rate of brood rearing before the honey flow started.

Bee parasites.—The North Dakota station found a previously unreported dipterous parasite of adult honeybees belonging to the family Conopidae. It also attacks bumblebees and other wild bees. As yet it does not appear to be very serious but may become so. Dead bees were often found in colonies where the parasite had gained a foothold.

ANIMAL PRODUCTION

FEEDS AND NUTRITION

Feed value of corn cut at different stages.—In a study of the composition of corn at different stages of growth, reported by the North Dakota station, it was found that "in the ear and fodder the greatest production of dry matter and its several constituents was either reached or approximately reached at the glazed

stage. This evidence, together with the observations that after the glazed stage there was a large gain in the daily increase in the dry matter content and in the mechanical loss of dry matter of the stover, indicates, as far as production of feed is concerned, that the corn plant may be considered mature at the glazed stage." (See also p. 21.)

Calculating rations.—Various methods of calculating rations for farm animals have been proposed and used from time to time. One of these is the energy-production coefficients method proposed by the Texas station and based upon the work of Kellner, Armsby, and others. A recent bulletin of that station gives the energy-production coefficients for ruminants of a large number of American feeds, as well as the digestion coefficients from which they were derived by factors varying with the nature of the feeds.

Computing net energy of feeds.—The Pennsylvania Institute of Animal Nutrition contributed an improved method of computing net energy values of feeding stuffs, which presents certain advantages over earlier methods used by the institute. The new method involves the separate determination (1) of the net energy required for maintenance, (2) of the gain of energy by the animal, and (3) of the heat-increment value of the feed. In the method the maintenance requirement of net energy is obtained by subtracting the computed heat increment, due to the consumption of the feed, from the heat production of each period, in accordance with the principles outlined by Armsby. To this is added the gain of energy by the animal in each period, as obtained by subtracting the total heat production from the total metabolizable energy, and the result represents the total net energy of the ration, from which the net energy value of the feed is computed.

Energy value of alfalfa hay.—The gross energy value of alfalfa hay per pound of gain in sheep was found by the Illinois station to average 2,596 calories. After deducting the maintenance requirement from the total intake of alfalfa hay it was found that the net energy value of the hay consumed above maintenance averaged 32.6 therms per 100 pounds, which compares well with that given by Armsby for alfalfa hay as determined with steers, using the respiration calorimeter.

Vitamin requirements.—Results of investigations reported by the Minnesota station indicate (1) that another or other vitamins than B and C are required for growth, (2) that the hitherto unknown factors reside in natural

foods, including milk and its unpurified constituents, and (3) that the functions of reproduction and lactation each demand either special combinations of the known biological food units, or specific units of a vitamin nature. The fact that second generation rats were reared and reproduced normally on a synthetic diet supposed to lack the fertility vitamin raised some doubt as to the existance of such a vitamin. Great difficulty was encountered in successfully weaning the young unless milk was added to the mother's food while nursing her young, supporting the belief in the existence of a special factor or special factors necessary for normal lactation in this animal.

The existence of a "fertility" factor in the absence of which degenerative changes take place in the testes and fertility is impaired despite excellent somatic growth is indicated by experiments with rats at the Connecticut State station. The addition of lettuce to the basic ration prevented the testicular degeneration, the effect of the lettuce being due to its richness in the antisterile vitamin E. The presence of this vitamin seems necessary for normal reproductive functions and germ cell maturation.

Action of indolinones on polyneuritis.—A study by the Minnesota station of beta-methyl and beta-propyl indolinones as to their action on polyneuritis in pigeons showed that neither compound was able to protect the birds against loss of weight on a polished rice diet or against the incidence of polyneuritis. Beta-methyl indolinone had a slight curative effect. Thyroxin, an indolinone-like compound, failed to protect, and pilocarpine hydrochloride had no preventive properties.

Nitrogen metabolism of molting fowls.—The Nebraska station found wide variations in the nitrogen eliminated by birds on a nitrogen-free diet. Molting caused great irregularities in the nitrogen metabolism of fowls. The addition of cystine markedly increased the utilization of a casein ration by molting birds.

Mineral requirements.—The mineral requirements of farm animals have been the subject of investigation by many of the experiment stations. The matter is of special importance in the case of growing and gestating animals and in dairy cows, in which bone building and milk production make the demand for mineral matter particularly great. Deficiency of mineral matter is often the cause of depraved appetite, leading to bone chewing and similar habits which may in time lead to disease. The so-called loin disease of cattle reported by

the Texas station appears to be an example of this and may apparently be corrected by insuring an ample supply of mineral matter in the feed of the cattle. (See also p. 55.)

The modern dairy cow, as the Michigan station points out, "is a highly specialized machine for the production of milk, which is rich in mineral salts, especially lime and phosphorus. Not only has the tremendous increase in milk production caused a greater mineral requirement, but the feeds used today are often grown on soils depleted in the essential mineral elements, resulting in a deficiency in the crops grown on such soils." The station found that the need of both growing and milking cattle for mineral matter was met by allowing free access to a mixture of 2 of bone meal to 1 of salt.

An exclusive wheat ration was found by the Washington station to be deficient in sodium for normal growth and reproduction of rats. From the results it appears that 0.23 per cent of sodium is too small an amount, that 0.53 per cent is the most satisfactory when both growth and reproduction are considered, and that 0.79 per cent and amounts above this are detrimental.

Iodine is now generally recognized as essential in the nutrition of mammals, and much attention is being given, particularly in goitrous regions, to the supply of it in food or water or both. The Illinois, Iowa, Montana, Ohio, Washington, and Wisconsin stations, among others, have contributed to the knowledge of the subject.

Recent experiments by the Iowa station show that feeding of iodine in the form of potassium iodide to young growing swine in dry lot and on rape pasture resulted in increasing the average daily gain approximately 10 per cent and decreased the feed required for 100 pounds of gain 10 per cent. The pigs given potassium iodide made greater growth in height, length, and leg circumference. Inasmuch as swine may be handicapped because of a deficient supply of iodine, and yet show no gross or unusual signs of goiter or other iodine deficiency troubles, the Iowa station thinks it is good practice in goitrous regions to use iodine in the form of iodide in the feeding ration, putting it in the drinking water, or with the feed, and using from one-third to an ounce of either sodium or potassium iodide to the hundred pounds of mineral mixture, which is kept before swine at all times.

Range cattle given an ounce per head daily of a mixture of a finely ground limestone, spent bone black, and potas-

sium iodide, with salt ad libitum, showed increased daily gains, decreased food required per 100 pounds of gain, and increased selling price.

Lambs of ewes given 2 to 8 grains of potassium iodide daily were impaired in vigor and resistance to disease. Iodine was eliminated in the milk of the ewes for 5 to 15 days after discontinuing the dosing.

HORSES

Injurious effect of wide rations on horses.—Feeding horses an extremely wide ration, mainly oat straw, even for a few months of each year was found by the South Dakota station to result in permanent injury to health and efficiency. There was a sacrifice of bone structure to maintenance of life. There was a decline in the ability of the horses to digest all nutrients except fat, the nutrient most relied on for energy upkeep. In case of the fats the digestive capacity was on the average more than doubled, notwithstanding a heavy decrease in the digestion coefficient of the ration as a whole.

CATTLE

Profitable cattle feeding in Arizona.—Cattle feeding in Arizona can, according to the Arizona station, be made profitable in conjunction with other farming operations, success depending upon the efficient use of the farm roughages—alfalfa hay, silage, pasture, and cottonseed hulls—supplemented with cottonseed meal and, under certain conditions, grain, and upon the development of an outlet for good fat cattle in the California market.

Profitable use of roughage in cattle feeding.—A profitable means of utilizing roughage when it is abundant on the farm is, according to the Indiana station, to winter steers on it, reserving the grain feed for summer use. Cattle of good quality can often be fed with advantage in this way. Corn silage was found to be a readily available and economical feed for fattening cattle.

Carrying capacity of pastures.—The North Dakota station found 10 acres of pasture per steer more than enough for maximum gain per head. One steer to 7 acres produced the maximum gain. Five acres per steer did not provide enough feed to produce a maximum gain during a period of five months and was overgrazed. With one steer to 3 acres the pasture was seriously overgrazed and the animals underfed. Deferred and rotation grazing with one steer per 4.4 acres provided enough

feed to give a gain about 10 per cent below the maximum, with no serious injury from overgrazing.

Dry lot v. pasture for fattening steers.—Larger gains were made in experiments at the Illinois station by cattle fed in dry lot than on pasture, but the pasture gains were somewhat cheaper. Bluegrass proved slightly superior to sweet clover pasture. Considerably larger gains were obtained from a ration of shelled corn, cottonseed meal, and corn silage than from any other ration used.

Soft corn for beef cattle.—On the basis of the amount of beef obtained per acre, various methods of feeding soft corn tested by the Illinois station ranked as follows: (1) Ear corn silage, (2) shock corn, (3) gathered from field, and (4) corn pastured in the field. However, all methods gave results that would be considered satisfactory, proving that soft corn is a valuable feed for fattening cattle, the difference between its feeding value and that of sound corn being surprisingly small. Based upon the dry matter content, the soft corn was the more efficient feed. In appearance the quality of the beef of cattle fed sound corn, however, was superior to that of the beef produced on soft corn. The sound corn carcasses contained 2 per cent more fat and 2 per cent less lean than the soft corn. No difference in palatability was observed.

Calf meal gruel.—Calves were successfully raised at the New York Cornell station on a calf meal gruel, consisting essentially of 250 pounds of yellow corn meal, 250 pounds of red dog flour, 150 pounds of ground oat groats, 150 pounds of linseed oil meal, 100 pounds of ground malted barley, 100 pounds of soluble blood flour, 10 pounds of calcium carbonate, 10 pounds of precipitated bone meal, and 10 pounds of salt, and having a composition of water 9.3 per cent, ash 5.1, protein 24, crude fiber 3.5, nitrogen-free extract 53.7, and fat 4.4 per cent. The gruel was made by mixing the calf meal with water at about 100° F. in the proportion of 1 to 5 by weight. It was fed three times a day.

Acetic and propionic acids and ethyl alcohol was found by the New York Cornell station in the feces of calves fed on a cereal-gruel diet. This was taken to indicate "that young calves do not have the power to completely digest large amounts of carbohydrates consisting essentially of starches. Therefore the partially digested food residues are acted upon by bacteria, resulting in the production of acids and alcohols."

Concentrated rations for calves.—The Michigan station found that calves fed milk alone, milk and grain, or grain alone died with symptoms of tetany and frequently showed bone changes similar to rickets in other animals. The addition of various mineral supplements gave only temporary relief. Cod-liver oil showed little if any curative effect on the trouble. A high leucocyte count and low calcium content of the blood indicated that death on the concentrated ration was due to toxemia.

Feeding baby beeves.—Satisfactory baby beef was produced at the Kansas station on a ration of shelled corn, cottonseed meal, and sorghum silage. The calves gained 2.08 pounds per day, paid the market price for shelled corn and cottonseed meal, and left a return of over \$5 per ton for sorghum silage, which was produced at the rate of 18 tons per acre. A higher degree of finish and a higher selling price per hundred-weight were secured when alfalfa hay was added to the ration; and the longer this was fed as a part of the roughage the greater was the degree of finish.

Corn and cob meal proved to be a superior feed for fattening baby beeves and shelled corn to be excellent for finishing, in experiments at the Minnesota station. Ground barley was used satisfactorily in place of corn, although it did not produce quite so good gains toward the close of the period, and less pork was made by the hogs following the steers. The addition of oats to a ration which included corn did not prove profitable. As a rule, it did not pay to grind shelled corn or oats for baby beeves. The purchase and use of linseed meal were usually profitable. It was necessary to supplement silage with a protein concentrate. As a rule, it was most profitable to feed baby beeves until they were well finished before marketing them.

Effect of age and sex on gain in cattle.—In a comparison at the Nebraska station of 2-year-old steers, 2-year-old spayed heifers, yearling steers, yearling spayed heifers, yearling open heifers, steer calves, open heifer calves, and spayed heifer calves fed the same ration, the 2-year-olds made the most rapid gains, the steers gaining slightly more than the heifers. Of the yearlings the open heifers gained more than either the spayed heifers or the steers, whereas in the calf class the steers gained materially more than either of the heifer classes. Calves made the most efficient use of feed.

In experiments at the Arizona station the most efficient use of feed was made by yearling steers, the economy of gains

diminishing with older cattle. A greater spread between buying and selling prices was required with older cattle. The records made by yearling heifers were excelled slightly in almost every respect by those of yearling steers, but the heifers had a more even distribution of fat and reached a market finish 10 days earlier than did the steers.

Silage for cattle.—The silo has proved, in experiments at the Arizona station, to be a better and less wasteful method of storing hegari for feed for cattle than stacking. Steers fed the silage made larger and more economical gains and attained a higher market value than did those fed dry forage. Heading, threshing, or grinding the grain for feed did not prove profitable in these experiments. Supplementing hegari silage with grain increased the dressed weight of the steers.

Mixed silage made of soy beans or cowpeas with corn or cane kept well, was more palatable to beef and dairy cattle, and produced more milk and butter than silage from corn alone, in experiments made by the Arkansas station. Corn made into silage was equal in feeding value, pound for pound of dry matter, to corn fodder ground to a meal.

SHEEP

Feeding range lambs.—Average range lambs were successfully fattened for the spring market by the Oregon station in 60 to 90 days on grain and alfalfa. Lambs to be marketed in March and April were fed alfalfa alone until 60 to 90 days before they were to be marketed and then given grain at the rate of 1 pound per head per day in addition to all the hay they would eat. Lambs on hay alone made but little gain, but the increase in market price during the winter months usually gave a fair return for the hay.

Soy beans for lambs.—The Illinois station found that soy-bean hay, although not fully equal to alfalfa hay, may be used to advantage in place of alfalfa in the rations of fattening lambs. Soy beans, whole or ground, were not so palatable as soy-bean oil meal or linseed-oil meal and gave somewhat slower gains. There was no advantage from grinding the soy beans. Soy-bean oil meal used as a supplement to shelled corn and soy-bean straw gave somewhat more rapid gains with slightly less feed per 100 pounds of gain than did linseed-oil meal. Soy beans and soy-bean oil meal were successfully used by the Indiana station as substitutes for cottonseed meal in rations for fattening lambs. The gains were as rapid

and as economical with soy beans as with cottonseed meal. Lambs fed soybean oil meal sold as high on the market as those fed cottonseed meal. Those fed soy beans sold for approximately 10 cents less per 100 pounds.

Sorghums v. corn for fattening lambs.—In tests at the Texas station grain sorghums showed practically the same feeding value as corn.

SWINE

Inbreeding.—The advantages of limited inbreeding were shown in an experiment by the Oklahoma station. The limited inbreds were produced by matings of half brothers and half sisters, the controls being from unrelated parents. The limited inbred litters averaged 7.2 pigs, the controls 7; and the average number weaned was 4.6 for the inbreds and 2.5 for the controls. The average birth weight of the inbreds was 2 pounds and of the controls 2.2 pounds. The average weight at weaning (60 days) was 32.2 pounds for the inbreds and 22.4 pounds for the controls, while the percentage of pigs alive at weaning time was 63.9 for the inbreds and 35.7 for the controls. The percentage of males in the inbred litters was 58.3 and in the controls 50.

Types of hogs.—Studies of the relation of feed to growth of lard type (Poland China) and bacon type (Yorkshire) pigs, by the Missouri station, showed no large or consistent differences in the physical or chemical character of the carcasses of the two types. The cost of gains in protein increased rapidly after the animals reached a weight of 200 pounds. On the other hand, gains in fat became constantly less expensive as the pigs grew from 100 to 300 pounds. A little over 40 per cent of the net energy consumed by the animals was stored in their tissues. The calculated daily maintenance requirement (including bodily activity) was approximately 2,850 calories per square meter of body surface and 50 calories per kilogram of live weight. The surface area of the animals was calculated by the following formula: $S = L^0.6 \times W^{0.4} \times K$, in which S is the surface area in square centimeters, L is the length of body in centimeters, W is the weight in kilograms, and K is the constant 175. L is obtained by measuring with a tape from the point of withers to the root of the tail.

The Illinois station found that hogs of the intermediate type showed slightly higher dressing percentages than hogs of the rangy type, and the intermediate carcasses were in better condition.

Hogs self-fed on alfalfa pasture produced the fattest soft carcasses. The rangy carcasses contained more skin and bone than the intermediate carcasses. The intermediate carcasses produced better hams and bacon than the rangy carcasses. Difference in cutting percentages was small. The intermediate type proved to be superior to the rangy type both in dry lot and on pasture.

In a comparison of small, medium, and large types of hogs at the Iowa station, the large type required the least feed to reach a market weight of 300 pounds and the small type the greatest. The medium type, however, made a greater daily gain and required 30 days less than the large type and 41 days less than the small type to reach a 250-pound market weight.

Feeds and rations for hogs.—Much of the station work with swine has been of the nature of relatively simple comparison of various combinations of feeds. The effort in most cases has apparently been to obtain well-balanced and efficient, as well as economical rations with the feeds most readily available, and in this respect the work has given valuable practical results, particularly in the way of determining the extent to which one feed may efficiently replace another in the ration, profitable supplements to commonly used rations, and the value of newly introduced feeds. At the same time light is being thrown on questions of vitamin requirements and need of mineral supplements. Some results of recent station work with hog feeds and rations are briefly as follows:

A ration of yellow corn and tankage was improved by the South Dakota station for the winter feeding of fall pigs by adding chopped alfalfa and oil meal or buttermilk. Ground barley was a satisfactory substitute for part of the corn in the ration.

Dried, semisolid, or creamery buttermilk was found by the Minnesota station to be somewhat more effective in pork production than tankage, but the commercial buttermilk feeds were somewhat less economical as sources of protein than either tankage or creamery buttermilk. The three forms were about equally efficient in experiments at the South Dakota station. Semisolid buttermilk and tankage proved superior to tankage alone in experiments at the West Virginia station.

Skim milk was the most satisfactory protein supplement for weanling pigs tried by the Minnesota station, but tankage with rape pasture gave nearly as good results. Tankage was decidedly inferior to skim milk in dry-lot

feeding, but with good pasture, such as rape, there was little difference between the two.

Fish meal and semisolid buttermilk proved superior to tankage and semisolid buttermilk for young pigs in experiments at the West Virginia station. The addition of 5 per cent of fish meal to a ration of corn and shorts was found by the Florida station to increase the average daily gain 0.24 pound and to save 155.7 pounds of grain for each 100 pounds of gain. A comparison of fish meal and meat meal fed with shelled corn showed the fish meal to produce 50 per cent larger daily gains. Meat meal and cottonseed meal, equal parts by weight, fed with shelled corn, gave a slightly better gain than the fish meal and cottonseed meal. Pigs receiving fish meal made more rapid and economical gains in experiments at the North Carolina station than those receiving soy-bean meal. The soy-bean meal was very palatable and when fed under the "free-choice" system the pigs consumed more than was necessary to balance their ration.

Ground rye was found by the Wyoming station to rank above shelled corn for producing rapid gains in pigs, and less grain was required with rye than with hull barley, bald barley, or shelled corn. Pigs fed corn or bald barley dressed a higher percentage of carcass to live weight than those fed rye or hull barley. The pigs receiving bald barley, rye, or shelled corn finished with the fat in good hard condition, while hull barley produced a flabby, oily fat. In experiments at the Minnesota station pigs fed rations containing a large proportion of rye did not make satisfactory gains and the feed requirements were abnormally high. The most satisfactory results were obtained by feeding a ration of 50 per cent ground rye and 50 per cent creamery buttermilk. Attempts to supply the necessary protein by feeding milk casein and to make the vitamin content of the ration satisfactory through the use of cod-liver oil were not successful.

Buckwheat middlings proved superior to wheat middlings as feed for pigs, in experiments at the West Virginia station. A yeast-fermented mixture of rye, oats, tankage, and mineral mixture produced somewhat more favorable gains in pigs, in experiments at the Michigan station, than did a similar unfermented mixture, but the advantage gained did not cover the cost of the yeast. Yeast-fermented buckwheat middlings and corn proved superior to unfermented wheat middlings and corn,

in experiments at the West Virginia station.

Peanuts and soft pork.—Experiments at the North Carolina station showed that every pound of oil in peanuts fed to pigs required 2.25 pounds of starch in the the hardening feed. Hardening feeds fed after the peanuts produced harder pork then when fed with them. Hogs weighing less than 150 pounds showed a greater tendency to softness than those weighing more.

The Georgia station found that pigs weighing about 100 pounds, fed peanuts for a gain in weight of about 40 pounds, could not be hardened by feeding corn without bringing them to a weight considerably beyond the limit of economy. Experiments with peanut oil added to standard rations showed that an animal weighing 125 pounds can consume 300 grams of the oil daily with no apparent physical disturbances.

Coconut meal for pigs.—Good results in feeding coconut meal to pigs were obtained by the Guam station. Pigs fed coconut meal with mineral mixture and pasture consumed 19.25 pounds of meal per pig per day for 80 days and made an average gain of 0.8 pound per day at a cost of 2 cents per pound, with no harmful effects. With free access to corn and coconut meal the pigs ate more of the latter than is generally recommended.

Alfalfa hay for wintering brood sows.—The use of alfalfa hay considerably reduced the feed cost of wintering brood sows, in experiments at the Delaware station. Sows consumed 2.35 pounds per head of the leaves daily, with a saving of 27 per cent in cost of concentrates over a lot fed corn and tankage.

POULTRY

Basal heat production of chicks.—The body surface of White Plymouth Rock chicks can, according to the Illinois station, be estimated by the formula $S=5.86 W^{.5} L^{.6}$, S being the surface area in square centimeters, W the live weight in grams, and L the rump-to-shoulder distance in centimeters. The average basal heat production of White Plymouth Rock cockerels per square meter of body surface per day was found to be 849 calories, and for capons 768 calories, these figures applying to birds from 2.5 months to 1 year of age. For younger birds the figures may be much greater.

Grain v. grain and mash for laying hens.—In a comparison by the South Dakota station of hens fed ordinary farm grains alone with those receiving the same ra-

tion plus 20 per cent tankage mash, the cost of feed being about the same, the mash-fed hens laid a third more eggs than those receiving grain alone. The hens receiving grain alone became excessively fat and stopped laying before those fed mash.

Meat in rations for egg production.—A mash containing 20 per cent meat scrap was found by the Kentucky station to yield more eggs and more profit than one containing 5, 10, or 15 per cent. The maximum egg yields and greatest returns were obtained when a mash containing 10 per cent of meat scrap was fed in addition to skim milk to supplement the grain ration. Hens receiving cottonseed meal during an 11-month period at the Texas station produced 123 eggs per hen, whereas those receiving meat scrap produced 147 eggs per hen. The feed consumed by the hens receiving cottonseed meal amounted to 5.8 pounds per dozen eggs, and by those receiving meat scrap 5.5 pounds. Fish meal was equal to meat meal for egg production in experiments reported by the North Carolina station.

Soy beans for laying hens.—In view of the fact that cereal grains are unsatisfactory as the sole constituents of rations for laying pullets and that animal protein concentrates, while greatly improving the rations, are expensive, the Indiana station has attempted to find efficient protein supplements from other sources. It found that soy beans or their by-product soy-bean oil meal gave practically the same results as the animal proteins when the ration was properly supplemented with minerals.

Soy beans were found by the Missouri station to be a satisfactory substitute for meat scrap in rations for laying hens if properly supplemented with mineral mixture (1 part of salt to 4 of bone meal). In the experiments from which the conclusion was drawn, a basal mash, consisting of equal parts of bran, shorts, and corn meal, to which was added 30 per cent of soy bean meal and 5 per cent of mineral mixture, was used. This mash was fed *ad libitum*.

Cottonseed meal for egg production.—In a comparative test, by the Arizona station, of protein supplements, cottonseed meal rations produced 75 eggs, meat scrap rations 105 eggs, and dried-buttermilk rations 111 eggs per bird in the same period of time. The New Mexico station found that a ration containing cottonseed meal produced a dozen eggs more cheaply than one containing tankage as a source of protein, but as the tankage-fed hens produced more eggs, there was a slightly larger

profit over feed cost. During the months when eggs brought less than 35 cents per dozen the cottonseed meal hens made the larger net profit, while during the months when eggs were higher priced the tankage-fed lot gave the larger profit. The price of eggs would therefore seem to be the determining factor as to whether or not cottonseed meal can be fed to advantage.

Milk products for growing chicks.—The Minnesota station found that with milk by-products available at low or no cost, an economical ration for young and growing chicks is the hull-less grains and all of such milk products as the chicks can be induced to consume. Both dried buttermilk and condensed buttermilk were found by the Kentucky station to be efficient commercial sources of protein and desirable for use when skim milk or buttermilk is not available on the farm. Experiments at the New Mexico station showed that milk is an economical source of protein when fed alone with scratch, but tankage is more economical than milk when the by-products of grains and grains themselves are used for a portion or as the entire mash mixture. Adding milk to a ration already high in animal protein was not economical. Experiments reported by the North Carolina station indicate that dried milk, condensed milk, meat meal, and fish meal were of about equal value as sources of protein for young chicks.

Animal protein for growing chicks.—The Nebraska station found that growing chicks during the first nine weeks of their growth period tolerated and even made good use of animal protein concentrates to the extent of 19.5 per cent of the total ration, when added to a mixed ration of corn, wheat, and barley plus minerals. The growth rate was progressively improved as the amount of protein was increased to 10.4 per cent of the total ration.

Vitamin and light requirements of fowls.—Chicks were successfully raised by the Missouri station on synthetic diets, with comparatively low mortality. Leg weakness, which occurred in some cases, was cured by adding rich sources of vitamin B, but exposure to direct sunlight was of no apparent benefit. Meat protein substituted for part of the casein did not improve the diet. When foods such as dried egg yolk, polished rice, and dried liver were added, growth was markedly accelerated and practically the optimum rate was attained. Using extracts of liver was of no benefit. Chicks receiving diets containing extracted polished rice grew at a subnormal rate, but those receiving

a diet containing 1 per cent of the extracted material grew at approximately a normal rate and appeared normal in all respects. The growth-promoting factor carried by the polished rice was apparently removed by extracting with dilute acetic acid.

Chicks exposed to sunlight were at all times in better condition than those kept in the laboratory, in experiments at the Illinois station, indicating that results of laboratory experiments with vitamin-deficient rations can not always be safely applied to farm conditions. In these experiments the vitamin A deficiency seemed to be much more serious in retarding growth and increasing mortality than vitamin D deficiency.

"Nutritional roup," according to the Kansas station, is caused by a lack of vitamin A and not a lack of vitamin D. Exposure to ultraviolet light was shown to enable the hen to put vitamin D into the eggs.

The importance of light in the normal growth and development of chickens received added confirmation in experiments reported by the Maine station. The failure in growth of chicks receiving insufficient ultraviolet light was traced to imperfect development of bone tissues. Although an abundance of bone-forming material was present in the food and blood, it was not deposited in the bones in sufficient amount. Exposure to ultraviolet light increased the hatching quality of eggs but did not increase the number of eggs laid or the fertility of the eggs to any appreciable extent.

Exposure to direct sunlight proved to be a very effective means of preventing leg weakness in chicks at the Ohio station. One-half hour of direct sunlight was more effective in curing the trouble than the feeding of green clover.

Relation of body weight to egg production.—In a study of the relation of body weight to egg production and of the most effective means of maintaining the best weight for this purpose, the New Jersey stations found that regardless of age the bird must be in good flesh in winter if satisfactory egg production is to be realized. One of the best ways to bring this about was found to be to feed heavily on scratch grain throughout the summer. From 4 to 4.5 pounds appeared to be the best body weight for the group of Leghorns studied.

The West Virginia station found no apparent direct correlation between body weight and egg weight in White Leghorns. The average size of egg apparently had no relation to the num-

ber laid. The ration, however, had an influence on the size of the egg.

Variations in eggs.—Marked variation in size, color, and shape was found by the North Dakota station in the first eggs laid by pullets of the same variety. Weight variations ranged from 16 to 26 ounces per dozen. Some pullets laying small eggs at first soon produced normal-sized eggs, while others never did so. The shape and color of the egg of any individual varied but slightly. There appeared to be a relation between the eggs produced by a hen and those of her progeny, especially as to color and probably as to size and shape.

Growth of progeny of heavily fed and poorly fed hens.—In experiments at the West Virginia station there was no significant difference in the rate of growth of chicks hatched in the spring from eggs laid by birds fed for heavy production during the preceding winter as contrasted with the growth of the progeny of fowls poorly fed for egg production.

Incubation in dry climates.—It is particularly difficult to maintain proper moisture conditions in the incubation of eggs in a dry region like that of New Mexico. The New Mexico station found the use of trays of wet sand in the bottom of the incubator to be an economical and effective means of improving the moisture conditions and increasing the hatch, proving better than using a water pan or sprinkling the eggs. A temperature of 101° F. for the first week, 102° for the second week, and 103° for the third week gave the best hatches. Cooling the eggs during incubation appeared to be advantageous. The head radiation type of incubator proved to be best under the conditions, with no marked choice between hot water and hot air types.

Growth of the chick embryo.—The embryo of fowls showed a marked acceleration in growth at about the twelfth day of incubation in experiments at the Illinois station, reaching a maximum on the sixteenth day. A marked retardation of growth occurred on the seventeenth day. During the course of incubation the weight of the egg decreased 11 grams, the weight of dry substance about 3.5 grams, and the energy value about 28 calories. There was a distinct transfer of calcium from the shell to the embryo.

DAIRYING

Breeding.—The dam's record is, as a rule, a poor guide as to her ability to produce high butterfat-producing

daughters, according to studies with Guernseys reported by the Missouri station. On the other hand, the daughter progeny performance of a sire is a reliable index of the son's transmitting ability to his daughters; therefore, bulls from proved sires of large-producing daughters should be given major consideration in breeding for high production. From a study of the progeny performance of Guernsey sires, based on the average mature equivalent fat production of the daughters and their dams, the station found that "the average production of a sire's daughter was a better index of his transmitting ability to his sons and through them to his granddaughters than is the dam's own record of production an index of her transmitting ability to her sons and through them to her granddaughters. In other words, a proved sire of high producing daughters, or a son of a proved sire is, on the average, greatly superior to a son of a high-record cow in transmitting high production to his daughters."

In a study of inheritance of milk production by means of pedigrees the Maine station found little or no influence of inbreeding, relationship, or famous ancestors on the production of dairy sires. Intensive inbreeding experiments, especially with small animals, mating brother and sister for a number of generations, has generally resulted in concentration of the prepotency of the animal but also in decline in vigor and probably fertility. It appears from this study that the parents and grandparents, sisters and half sisters, and to some extent cousins are the important relatives on which to base an estimate of the productive worth of the animal and that the animals on which greatest dependence may be placed in reading a pedigree are the recorded performances of the dam, full sisters, and half sisters, and next to these stand the recorded performances of the grandparents.

Type appears to have some relation to milk production but little or no relation to butterfat percentage, according to the Maine station. Pedigree is of doubtful value, except when accompanied by records on a large number of animals found within the pedigree. The choice of dairy cattle by their performance is shown to be a much more important means of selecting and breeding to increase productivity of the herd.

Breeding studies of the Texas station emphasize the value of the progeny test. It is held that much of the propaganda in favor of purebred sires is too sanguine. Not all registered bulls

prove to be good sires, and bulls with famous ancestors two or three generations back may be incapable of improving a herd. It is therefore considered a serious mistake to encourage a farmer to think that by merely using purebred sires and culling his cows he can invariably produce a herd with a high average of production.

Progress in developing a dual-purpose cow especially suited to the conditions in Alaska is reported by the Alaska stations. Several promising Holstein-Galloway and Galloway-Holstein crosses have been obtained, which appear to be intermediate between the parents in milk yield and fat content of the milk, and are hardier than the Holstein.

Vitamin and light requirements for calves.—The Minnesota station reports that calves fed from birth on rations deficient in vitamin A but adequate in other respects showed characteristic symptoms in two months and survived only to the age of three or four months. Calves fed rations deficient in vitamin C made a normal growth to the age of 1 year and appeared to be normal on a ration so low in this vitamin that guinea pigs on the same ration died of scurvy within 20 days. No symptoms of scurvy appeared in the calves. Guinea pigs fed liver from calves raised to 1 year on a ration devoid of vitamin C were not protected from scurvy, indicating that the vitamin is not synthesized in the body of the calf. Of two lots of calves fed for 21 months on the same ration, one being kept in complete darkness and the other exposed to the direct rays of the sun daily, the calves in darkness showed no ill effects and, possibly, were in slightly better condition than those exposed to sunlight.

Mineral requirements.—A low mineral ration had no prolonged ill effects on the general condition of aged cows, in experiments at the Massachusetts station, the change in body weight being insignificant and the composition of the milk unaffected. Mineral supplements added to a low mineral ration had no pronounced effect. However, the reproductive functions were seriously disturbed by the low mineral ration, and recovery was very slow.

The alkaline reserve in the blood was found by the Michigan station to be lower in case of cows receiving considerable grain in addition to roughage than in those receiving exclusively roughage. Unfavorable pasture conditions lowered but heavy milk production had no effect on the alkaline reserve, which is contrary to the generally accepted idea that lactation drains the

body of minerals necessary to keep up the alkalinity of the blood.

The importance of adding mineral supplements to the ration of growing heifers may be overemphasized, according to tests made by the Michigan station, which indicated that ordinary rations containing adequate energy and protein also contain ample minerals, especially lime, for proper growth and development. Certain mineral mixtures proved to be detrimental. Raw rock phosphate was found to have an injurious effect on the health of dairy animals and affected the appetite for food and water, and hence is not recommended as a supplement to feed for dairy cattle.

Hay and green feed.—The mineral requirements of dairy cows were not met by a ration containing timothy hay as the roughage, in experiments reported by the Ohio station. Alfalfa, clover, soy beans, and sweet clover gave better results. They apparently supplied not only lime but also the unknown factor which aids the animal in utilizing the lime. Green grasses or legume hays, carefully cured, supplied more of this factor than hays that had been unduly exposed to the bleaching effects of the sun. Cows on pasture stored larger reserves of lime than those fed in dry lot.

The beneficial effect of properly cured hay and green food on dairy cows was shown in experiments at the Michigan station. Cows fed rations containing adequate amounts of energy, protein, vitamins, and mineral matter but no hay or green food failed to shed their winter coats of hair properly and otherwise did not thrive. They also failed to reproduce properly. The addition of good hay or green feed corrected these difficulties. The hay was most effective when cured with exposure to as little sunlight as possible. The general conclusion was that "a good ration, one containing plenty of well-cured hay or one supplemented with abundant pasture, is the basis of proper nutrition of dairy cattle."

Silage as feed for dairy cows.—There are reported to be 500,000 silos in the United States, being especially numerous in those regions where dairying is most highly developed. More than 100,000 are reported from Wisconsin alone. The Wisconsin station has therefore given particular attention to the study of the process of silage making. The first significant change observed was the rapid disappearance of oxygen and increase of carbon dioxide, followed by rise of temperature and increase of acid. Various microorganisms were found to

take part in the process, but the conditions were especially favorable for the growth of the lactic acid group. "The bacteria produce profound chemical changes in the plant tissue. Many of the carbohydrates are converted into carbon dioxide, ethyl alcohol, and organic acids; the proteins are partly hydrolyzed into proteoses, peptones, amino acids, and ammonia." Of the aciduric bacteria present, the pentose fermenters were especially active. Aside from the breaking down of pentoses, the most of these organisms play an important rôle in formation of alcohol. Approximately 10 per cent of the dry matter, 25 per cent of the pentosans, and 25 per cent of the starch contained in the corn forage were destroyed as a result of ensiling for four months. Though inoculation with certain bacteria produced a more vigorous and sustained fermentation, it is not considered of practical importance under ordinary conditions. With corn of uneven ripeness it may be of advantage.

Cows fed corn silage maintained body weight better and produced approximately 10 per cent more milk and 6 per cent more butterfat, in experiments at the Indiana station, than those not fed silage but receiving about a third more digestible protein. The station concludes that the feeding of silage is necessary for economical dairy production.

Sorghum silage proved to be from 93 to 95 per cent as effective as corn silage for milk production, in experiments at the South Carolina station, and the sorghum yielded 14 tons of silage per acre as compared with 8 tons from corn. Cows fed corn silage produced more milk than those fed Napier grass silage, in experiments at the Florida station. In a comparison of sunflower silage with oat and pea silage, the Montana station found that when fed with alfalfa hay and a small grain ration there was practically no difference in the feeding value of the two silages, the daily yield of butterfat being practically the same; but the sunflowers yielded about twice as much per acre as the oats and peas.

Soy beans for milk production.—The steady extension of the culture of the soy bean and the various uses which may be made of its products have given rise to many investigations by the experiment stations, especially with regard to its feed value.

Ground soy beans are considered by the Indiana station one of the best protein supplements that can be used in the dairy ration, giving better results than soy-bean oil meal or linseed-oil

meal. The South Dakota station found ground soy beans to be more digestible and more efficient than old-process linseed meal for milk and butterfat production. The beans were readily eaten even when they were the sole concentrate. They did not appreciably affect the quality of the butter produced, but apparently temporarily increased the percentage of butter in the milk of certain cows. More milk protein was produced from a pound of total crude protein from peanut meal than from either cottonseed-meal or soy-bean-meal protein, in experiments at the Virginia station. The relative gross efficiencies in producing milk protein from total crude protein were peanut meal 29.6 per cent, cottonseed meal 27.8 per cent, and soy-bean meal 27.9 per cent. On the digestible crude protein basis the efficiencies were peanut meal 50 per cent, cottonseed meal 46 per cent, and soy-bean meal 45 per cent.

Soy-bean hay was more efficient for milk and butterfat production than alfalfa hay in experiments at the South Dakota station. The hay, however, was not so economical a feed as alfalfa hay because of the lower yield. In experiments at the Minnesota station soy-bean hay and timothy hay were about equally effective in milk and butterfat production. Cows receiving soy-bean hay required only two-thirds as much grain as did cows receiving timothy for the production of an equal quantity of milk. The soy-bean hay was very palatable, less than 3 per cent being refused.

Cottonseed meal for dairy cows.—It was found by the North Carolina station that the injurious effects on health, milk production, and reproduction of heavy feeding of cottonseed meal to cows on limited pasture could be corrected by adding to the ration such things as casein, cod-liver oil, butterfat, alfalfa meal, and calcium carbonate, or bone meal, which increased the content of vitamins A and B and mineral matter. When these were added the cows ate more cottonseed meal without injurious effect, produced more milk, and gave birth to normal calves.

Sweet sorghum seed as a dairy feed.—The percentage of butterfat in the milk and the total butterfat production were increased by substituting ground sweet sorghum seed for corn chop in feed for milch cows receiving a liberal ration of alfalfa hay, grain, and silage, in experiments reported by the Kansas station. There was no particular advantage as regarded maintenance of body weight and milk production.

Apple pomace as a dairy feed.—A comparison of dried apple pomace, dried beet pulp, and corn silage for dairy cows, by the Virginia station, indicated the feeding value of the pomace to be 75 per cent of that of the dried beet pulp. It was found to contain three times as much total digestible nutrients and two and one-half times as much digestible protein as corn silage, while dried beet pulp contained four and four-tenths times as much total digestible nutrients and four times as much digestible protein as the silage.

Carrying capacity of land for cows.—A rotation of corn, corn, oats, and sweet clover, with the addition of a nitrogenous concentrate during winter proved adequate, in experiments at the Illinois station, to maintain 1 cow for each 4 acres of land in crops. The winter ration consisted of corn stover silage supplemented with 1 pound per head per day of a protein concentrate. During the summer the cows were carried on sweet clover pasture.

Self-feeders for dairy cows.—Permitting dairy cows to have access to a number of different feeds in self-feeders was found, by the Illinois station, to be uneconomical, although after a time the cows tended to accustom consumption to requirements. Very great differences were found in the feed preferences of the cows. The method proved to be safe from the standpoint of the health of the cow.

Relation of size of cow to milk production.—In a study of the relation of the size of cow to milk production, the Maine station showed that in case of 385 Holstein-Friesian cows varying in age from 1.5 to 10.5 years, averaging 3.9 years, with an average 7-day milk yield of 338 pounds, the average measurements were shoulder height 52.8 inches, hip height 53.8 inches, body length 62 inches, rump length 20.4 inches, body width 21.3 inches, thurl width 19 inches, body girth 73.2 inches, and weight 1,088 pounds. The coefficients of variation ranged from 3.7 to 15.1, the most variable measurement being weight, the least variable height at hips. All of these body measurements were found to be related to milk yield, an increase in any one of them being associated with an increase of yield. The most important element predicting milk yield was weight, followed closely by body length, body width, or girth.

Feed cost of milk production.—From a study of the feed cost of milk production the Illinois station concludes that "the nutrients required for lactation per pound of milk, N_L , may be expressed as a function of the fat percentage of

the milk, t , as: $N_L = K_L (2.66+t)$. The nutrients required for maintenance per pound of milk, N_M (because of the nature of the relation existing between fat percentage and size of cow and between fat percentage and milk yield), may also be expressed as a function of fat percentage, as: $N_M = K_M (2.66+t)$. Consequently the total nutrients required for milk production per pound of milk, N_T , may be expressed as: $N_T = K_T (2.66+t)$. The cost in dollars per pound of nutrients is practically unaffected by fat percentage and consequently the feed cost (\$) per pound of milk, FC , may be expressed as: $FC = K (2.66+t)$. In these relations K_L , K_M , K_T , and K are constants so far as affected by fat percentage. The price differential for fat test as judged by the whole-milk markets of 101 cities seems to be tending to distribute about a mean which is approximately the same as the cost of production differential. The price of milk may be adjusted in proportion to the cost of production by the equation $P = \frac{P_b}{2.66+b} (2.66+t)$, in which P_b is the base price, b is the fat percentage to which the base price applies, and P is the price to be paid according to the fat test, t , of the milk delivered. This assumes that the cost of production is proportional to the feed cost of milk production, so far as affected by fat percentage."

Calculation of composition of milk.—The milk solids-not-fat and the total milk solids as determined in samples of mixed milk by chemical analysis were compared by the Illinois station with calculations made by the formulas—

$$\begin{aligned} \text{Total solids} &= \\ \text{Quevenne lactometer reading} &+ 1.2 \text{ fat}, \\ 4 & \\ \text{solids-not-fat} &= \\ \text{Quevenne lactometer reading} &+ 0.2 \text{ fat}. \\ 4 & \end{aligned}$$

This comparison showed that the calculated percentages of total solids and solids-not-fat were an average of 0.105 less than actual. Statistical analysis of the results indicated that when the suggested correction was made in this formula, the resulting percentages were sufficiently accurate for practical use in dairies where the determinations were made on samples of milk from a number of cows. A further comparison was also made between the calculated percentages of solids-not-fat and the actual percentage of solids-not-fat from 1,158 samples of individual cows. A larger correction

factor was needed to make this formula conform with the average for the individual samples, but owing to the greater variability among individuals, its use was not recommended where determinations are to be made on milk samples of individual cows.

Micrococci in milking machines.—Numerous species of micrococci were found by the New York State station to be associated with milking machines. The species most commonly found in the tubes and teat cups were, in the order of their probable abundance, as follows: *Micrococcus candidus*, *M. freudenreichii*, *M. casei*, *M. conglomeratus*, *M. epidermidis*, *M. varians*, *M. flavus*, *M. aurantiacus*, *M. luteus*, *M. albus* and *M. aureus*. It was observed that where the parts which come in contact with the milk are submerged in sterilizing solutions to prevent bacterial growth between milking periods, micrococci are found more commonly than other bacteria. The predominance of micrococci under these conditions may be explained by the fact that they survive the sterilizing procedures used better than the other bacteria present.

Determination of fat in dairy products.—Various new methods of determining fat in dairy products have recently been extensively exploited, with the result that a number of stations have thought it necessary to study their relative merits. Comparative tests by the Connecticut Storrs station of the Röse-Gottlieb, Babcock, and Gerber methods on milk and cream led to the conclusion that there is no advantage in introducing another method to replace the Babcock method for this purpose. Comparative tests of the Röse-Gottlieb, Troy-Fucoma, and modified Babcock method for the determination of fat in ice cream led to the conclusion that "both the Troy-Fucoma and the modified Babcock method seem well adapted for ordinary factory use where simplicity and rapidity of the test are important considerations; however, results obtained in this study would seem to make it questionable if their use is justified in instances where careful analytical results are desired." * * * In view of the fact that the Babcock method for milk and cream is generally used in the United States and is recognized as official it seems advisable to develop if possible a method using Babcock equipment rather than to introduce a new method requiring the installation of new equipment."

Composition of butter.—Analyses of 2,051 lots of exhibit butter, examined by the Minnesota station, showed an average of 83.46 per cent fat as compared with

82.21 per cent for 363 market samples taken in 1923 and 81.31 per cent for 1,000 market samples manufactured during the first four months of 1925. The average salt content of 2,051 exhibition samples was 1.76 percent; for 363 market samples in 1923, 2.23 per cent; for 1,000 samples of market butter in 1925, 2.31 per cent. The 230 samples scoring below 90.5 contained 1.98 per cent of salt as compared with 1.29 per cent in 366 samples scoring above 93.5. The results of analyses of butter from various sources showed the need and the advantage of more attention to standardizing and controlling the composition.

Butter making.—In experiments reported by the Illinois station no one neutralizer showed an advantage over another as far as the quality of the fresh butter was concerned, except that a slight bicarbonate flavor was noted where sodium bicarbonate was used. After storage for 60 days the butter made with soda ash or bicarbonate did not hold its quality as well as did that in which lime was used. With a combination of neutralizers, the best results were obtained when lime was used first, followed by soda ash or bicarbonates. The mixing of the two neutralizers before use resulted in a lower quality of butter. The butterfat losses in the buttermilk was greater when either soda ash or bicarbonate was used than when lime was used. Fat losses in buttermilk can be reduced by the addition of common salt and hydrochloric acid to the cream at time of churning.

Butter made from unripened sweet cream was found by the Utah station to score as high as that made from ripened cream and to keep much longer in cold storage without deteriorating. Adding starter to the sweet cream immediately before churning improved the flavor of the butter slightly and did not impair its keeping quality.

Cooling cream on the farm is both practicable and highly desirable, according to the Indiana station, which has devised simple and effective means of bringing this about. The station has shown that butter scoring 90 points or better can be made from cream cooled and delivered at intervals of four days or less, and that such butter will stimulate the consumptive demand and net better returns to both cream producer and the creamery man.

Whipping properties of milk and cream.—The New York State station found increased viscosity and decreased surface tension to be associated with good whipping quality. The viscosity increased with aging and with increased percent-

ages of fat. Pasteurization slightly reduced the viscosity of milk and greatly reduced the viscosity of cream. The effect of aging on viscosity was inhibited to a large extent by pasteurization. The surface tension of milk and cream decreased with an increased fat content, and it usually decreased with aging. Pasteurization usually increased the surface tension and aging would not reduce it to normal. The whipping qualities of cream were improved by increased percentages of fat and aging. Pasteurization had a slightly detrimental effect.

Roquefort cheese.—The California station reports successful manufacture of Roquefort cheese from goat's milk, cow's milk, or a mixture of the two, the goat's milk cheese being equal in quality to the imported. The average yield of Roquefort cheese from goat's milk testing 3.4 per cent butterfat was 10.34 pounds for each 100 pounds of milk. The factory procedure found most satisfactory is described.

Ice cream.—The fact that 250 to 300 million gallons of ice cream, or approximately 2.5 gallons per capita, are consumed annually in this country indicates the extent of such use of milk and its products. According to the Indiana station, this great consumption has indirectly been the cause of a great difficulty in ice cream making, namely sandiness, due to the necessity of making increased use of concentrated milk products. This defect is characterized by the presence of numerous hard, sharp, crystalline granules, which give the cream a gritty feel. Cream containing 7 per cent or more of milk sugar corresponding to 13 per cent or more of milk solids was generally found to be sandy. Twelve per cent of solids-not-fat is considered a safer limit and high enough for practical purposes.

In a study of the effect of different proportions of milk solids, fat, and sugar on the physical properties and quality of ice cream the Missouri station found that an increase in the milk solids increased the viscosity-titrable acidity, lowered the freezing point, increased the time required to freeze the mixture, and lengthened the rate of melting of the frozen mixture. Each additional increment of 2 per cent of butterfat to the mixture decreased the specific gravity and increased the viscosity. The overrun increased with an increase of fat up to 10 per cent but decreased above this, while the viscosity continued to increase. No direct relation was found between the fat content and the hardness of the ice

cream. An increase in the fat retarded the melting point. Each additional increment of sugar up to 12 per cent lowered the freezing point of the mixture, delayed freezing, increased the overrun, and improved the flavor, body, and texture. Thereafter the overrun was correspondingly depressed and the flavor, body, and texture became inferior.

Variations in texture of ice cream appear, according to studies reported by the New York State station, to be due not so much to the size of the incorporated air cells as to formation and growth in size of ice crystals and spines. The size of the air cells was not altered by variations in the composition of the cream, but homogenization reduced their average diameter about 50 per cent and the cells also became smaller as the freezing process continued. Sugar improved the texture by reducing the amount of ice formed. The protective colloid action of gelatin in inhibiting ice crystal growth was no greater than the action of casein. Milk fat prevented the formation of large ice crystals by mechanically obstructing their growth. Milk fat and solids-not-fat had a greater combined effect on texture than either alone. Homogenization increased the combined action of milk fat and solids-not-fat in making ice cream smooth as shown by a further reduction in the percentage of gelatin required to form a gel.

The organisms that cause "pin point" colonies in ice cream were shown by the Kansas station to be sufficiently resistant to heat to survive pasteurization and, apparently, some actually grow at pasteurization temperatures, resulting in some cases in the ice cream actually having a higher bacterial count after pasteurization than before. No satisfactory method of controlling these organisms was found.

DISEASES OF ANIMALS

Equine anemia.—A disease of horses apparently identical with that known variously as infectious equine anemia, swamp fever, infectious anemia, etc., is reported by the Nevada station. "The disease is characterized clinically by irregularly remittent fever, rapid emaciation, marked loss of energy, depletion of red blood cells in most cases, edema, usually bloody nasal discharge, and eventually death. The mortality is nearly 100 per cent, real recovery rarely, if ever, taking place. The disease is transmissible to other horses by the injection of infected blood

or splenic emulsion, the period of incubation being from about two weeks to several months. The etiological factor is apparently ultramicroscopic, since the disease can be reproduced by the injection of Berkefeld filtrates, and is not recognizable by ordinary staining methods in smears from the blood, tissues, or exudates and transudates. The natural mode of transmission is not known, but is most likely through the bites of insects. Methods of treatment thus far used have proved unsuccessful, killing the infected animals being necessary to prevent spread of the disease. A positive diagnosis can only be secured by animal inoculation. Animals other than equines are not susceptible to the disease."

Infectious abortion.—Infectious abortion continues to be a leading subject of investigation by many of the stations. The Connecticut Storrs station shows, from 11 years' records of the college herd having 16 reactors to 14 nonreactors, that the nonreactors earned annually about \$28 more per cow than the reactors. The loss in milk production for the 11 years chargeable to the presence of abortion in the herd was therefore \$4,984. To this may be added a loss of \$2,076 due to depreciation of the reactors and \$928 due to loss of calves, or a total of \$7,988 resulting from the presence of the 16 reactors, which amounts to about \$45 per year for each infected cow.

From studies of methods of making agglutination and complement fixation tests and of their diagnostic value, the Connecticut Storrs station concludes that "by paying particular attention to the production of a potent bacterial antigen which is at best but slightly anticomplementary, and by following the rules governing both the agglutination and the complement fixation tests, these methods may be applied satisfactorily in the diagnosis of infectious abortion. Their constancy and reliability make them indispensable in the study and control of this disease." The two methods are considered by the station of equal importance, though the agglutination test is by far the simpler and more economical. The use of both is recommended, one serving as a check on the other. Attention is called to the possibility of obtaining negative results by the two serological methods at or near the time of calving of infected animals, and further tests on such animals after an appreciable interval following the calving are recommended. The Washington station found the agglutination test for abortion to be of considerable value as a herd index of

the presence or absence of abortion infection, and where it was used repeatedly in an infected herd it was of value in determining infection in individual cows; but its value was limited when applied to individual cows in an infected herd the first time. Not infrequently recently-infected pregnant cows failed to show a reaction, subsequently aborted, and then, as a rule, developed the reaction.

In view of the great demand for help in eradicating infectious abortion from dairy herds, the Connecticut Storrs station has undertaken to test a limited number of blood samples for *Bacterium abortum* infection, charging a fee of 75 cents per sample "for the first general herd test and for each regular semi-annual or annual test following successful eradication, 35 cents each for the first immediate follow-up test during the period of elimination, and 25 cents per sample for each of the remaining follow-up tests. The lower charges for the follow-up tests are made possible by employing the agglutination method alone instead of the more elaborate procedure which involves both the agglutination and the fixation methods."

In a study of the location and longevity in calves of *B. abortum* ingested with milk, the California station found the organism to be quite generally distributed through the lymph glands of the head and digestive tract, and also in other parts of the body, while infection was present in the milk. The longest period in which they were recovered following the removal of infection was from the atlantal gland of one calf 7 weeks after infection was withdrawn, and in the posterior pharyngeal gland of another calf 11 weeks afterward. Blood tests of these calves showed that the ingestion of virulent organisms in quantity did not develop agglutinins in the blood, indicating that in the control of the disease by the agglutination test no dependence can be placed on the results of the test applied to the blood of calves. It was found that the organism passed through the entire digestive tract and was eliminated with the feces of suckling calves fed either artificially or naturally infected milk.

B. abortum probably does not persist in the tissue of newborn calves from prenatal infection or through ingestion of milk containing the organism, according to experiments reported by the Michigan station. No evidence was found that calves from infected cows are more susceptible to calves' diseases or that the breeding efficiency is impaired in any way.

Attempts to control infectious abortion by temporary isolation of aborting cows, destruction of fetuses and their membranes, and disinfection of stalls in which abortions have occurred, or through separating the reacting animals from the negative animals but keeping them in the same barn were unsuccessful at the Oregon station. The adoption of a system similar to the Bang system in tuberculosis control has given satisfactory results. The yearly average milk production per cow in the infected group was 35 per cent less than in the abortion-free group.

Abortion in cattle was controlled by the Washington station in a Holstein herd 60 per cent infected by "dividing the herd into two groups, based upon the agglutination reaction and keeping the two groups separated when they are at liberty. This necessitates having separate pastures in the summer and two open sheds in the winter. All of the cows are milked in the same barn by the same attendants. The negative cows are brought in first and stanchioned, after which the positive group is brought in. In liberating the cows from the stanchions after milking, the positive group is turned loose first. This simple precaution of taking the cows in and out of the milking barn prevents any possible chance of a negative cow licking the body of an infected cow. The cows are brought into the barn for the purpose of milking only, and while there are fed their grain. No hay is handled, stored or fed in the milking barn. The milking barn has two rows of steel stanchions facing outward, one along each side of the barn. The entire floor is concrete and there is the usual gutter the proper distance behind the cows, with a broad alleyway between." After milking the manure is removed and the floors washed and scrubbed. Variable and inconclusive results were obtained with bacterins and viruses.

About 47 per cent of positively reacting cows at the Minnesota station eliminated the abortion organism by way of the placenta or milk, or both, and 37 per cent of the vaccinated animals and 27 per cent of the unvaccinated animals acted as spreaders of infection by eliminating the organism. The organism was eliminated from three individuals which failed to react positively to the agglutination test. In one of these the organism was recovered from the placenta and milk, in the second from the placenta alone, and in the third from the milk alone. Infection of the male was attempted by

repeated injection of large amounts of living organisms into the urethra and sheath but with negative results. Bulls were infected by way of the digestive tract, but only after repeated drenchings, showing a marked resistance to infection in this way. Autopsy showed no involvement of the genitalia. Bulls giving a positive reaction to the serologic test often failed to harbor the organism in the genital organs. Heifers given the living organisms directly into the urethra and vagina gave only transient reactions.

Three cases of a recurrent fever in young men which appeared to incriminate *B. abortum* as the causative agent were studied by the Michigan station. In two of the cases an organism was isolated from the blood which resembled *B. abortum* culturally and serologically. The blood of one reacted in a dilution of 1 to 200, of another in a dilution of 1 to 1,000, and of a third in a dilution of 1 to 400, using *B. abortum* as antigen.

Infectious white scours and pneumonia in calves.—The Minnesota station found that calves that received colostrum were less apt to contract these ailments. The colostrum appears to contain protective agents, which are developed in the udder up to the time of parturition. Careful feeding was found to be an important measure in the prevention and treatment of the infections. The use of barley water or gruel prepared by adding hot water to ground barley proved a good milk substitute for sick calves. Colon bacilli of various types were found to be the causative factor in most outbreaks. Control measures suggested are segregation and isolation.

Normal immunity of cows and calves to *Bacterium coli*.—The blood serum of the cow was found by the Missouri station to possess a marked bacteriolytic action toward *B. coli*, but in the unsuckled calf the bacteriolytic action was weak and there was a deficiency in complement. Both increased after nursing and when calves were fed ordinary milk in place of colostrum. There appeared to be an increase in complement and probably in bacteriolytic action with age. Agglutinins were not present in the blood of the newborn calf but appeared upon suckling. There was no immediate appearance of agglutinins in the blood of milk-fed calves. It is thought that the augmented immunity reaction may be accountable in part for the observed resistance of the colostrum-fed calf to invasion by *B. coli*.

Retention of fetal membranes.—It was found by the Minnesota station that in healthy cows the fetal membranes are, as a rule, expelled within 4 to 6 hours.

When retained for more than 10 or 12 hours it is evidence of placentitis. Involution is seldom completed inside of 30 days. Retention of the fetal membrane retards involution and often causes inertia of the uterus, which may result in infection. Normal involution acts as a barrier to infection.

Paratyphoid dysentery of lambs.—A result of slow and improper handling of stock in transit is the incidence of fatal diseases of various kinds. A serious outbreak of paratyphoid dysentery in lambs was found by the Colorado station to be due to delay and improper feeding in shipment. Out of 30,000 lambs involved in the delayed shipments, approximately 2,000 died. The organism was isolated and the disease reproduced in normal lambs. Fasting lambs were found to be much more susceptible to the disease than those properly fed.

Swellhead of sheep and goats.—Investigation by the Texas station indicates that this disease has a direct relation to malnutrition or deficiencies in the feed or diet. The disease does not occur in flocks receiving supplemental feeds but is not uncommon when the animals are grazed without any other feeding. Treatment with Glaubers salts followed by a mixture of nux vomica, gentian root, and aloes gave good results.

Reliability of the tuberculin test.—Studies by the Minnesota station indicate that slight and atypical reactions to tuberculin should not be taken lightly or ignored. Cattle giving such reactions are very likely to give positive reactions or positive autopsies later. Nontuberculous cattle may be unusually sensitive to tuberculin and some may be artificially sensitized by its use, especially in ophthalmic work. Marked discrepancies between tests and the large percentages of unsatisfactory tests occurred in either repeatedly tested herds or in badly diseased herds.

Avian tuberculosis.—A steady increase of swine tuberculosis, as shown by abattoir statistics, is attributed, by the Nebraska station, in great part to infection of avian origin. Of 209 cases of tuberculosis in swine examined by the station, 185, or 88.5 per cent, were avian. Inoculation of guinea pigs alone was found to be insufficient for diagnosis. The station therefore suggests supplementing the microscopic examination with inoculation of both guinea pigs and fowls to detect the avian form. Tuberculin of mammalian origin often fails to detect avian tuberculosis and vice versa. Both avian and mammalian tuberculin should therefore be used in diagnosis. Mammalian tuberculosis is more virulent than avian in swine.

The selection of safe quarters and feed, the rejection of carcasses as food for swine, and above all the practice of hog lot sanitation, such as is now generally advocated for the prevention of the filth-borne pig diseases, are recommended as the best means of controlling the disease.

Yearling calves exposed to the droppings of tuberculous chickens were found by the North Dakota station to be readily sensitized to avian tuberculosis, as evidenced by positive reactions by both intradermal and subcutaneous tests with avian tuberculin, but not with bovine tuberculin. Pigeons and sparrows similarly exposed showed no infection. Feeding tuberculous organs from chickens to rats and barn and field mice failed to produce infection.

Calves injected with avian tubercle bacilli developed local lesions and gave good positive tuberculin reactions, with the intradermal test, in experiments at the Wyoming station. The local lesions resembled greatly those observed in the skin form of tuberculosis. The organisms were found to be alive and active in the lesions eight months after they had been introduced. They could be entirely removed by surgical operation and five months afterwards the calves failed to react.

Less than 1 per cent of the eggs from tuberculous fowls was found by the Minnesota station actually to contain living tubercle bacilli. No tubercle bacilli were found in or on the eggshell.

Fowl typhoid and cholera.—The North Carolina station concludes that there are morphological differences and differences in physiological reactions of the causative organisms of the widespread and destructive diseases fowl typhoid and fowl cholera that differentiate them as due to separate and distinct germs. The clinical symptoms, blood changes, and pathological anatomy of the diseases are sufficiently unlike to establish a basis for differential diagnosis. However, control measures that apply to avian typhoid should be effective in checking the spread of avian cholera.

Prevention of coccidial infection in chickens.—The California station found that feeding cultures of *Bacillus acidophilus* to chickens resulted in the implantation of the organism in the ceca. The pH value of the cecal contents was changed from the normal range of 6.0 to 7.4 to a range of 4.4 to 5.6 by feeding sufficient amounts of whole sweet milk, milk cultures of *B. acidophilus*, milk cultures of *B. acidophilus* plus lactose, lactose alone, or dry skim milk. Feeding chickens a mash containing 40 per cent dry skim milk not only protected

them against coccidial infection, but also stimulated rapid growth.

Condensed buttermilk diluted with water and kept before the chicks was found by the Texas station to be of value in reducing losses from chicks infected with coccidiosis.

Roundworm in poultry.—The thymus gland of baby chicks parasitized with the large roundworm (*Ascaridia perspicillum*) showed less than half the development of that of unparasitized chicks, in experiments at the Kansas station. The amount of sugar in the blood of the parasitized chicks became decidedly subnormal. Eggs of this nematode placed on the surface of the soil during the winter months were less viable when in the infective (coiled embryo) stage than when the eggs first left the bodies of the chickens. Many of the freshly laid eggs survived freezing temperatures.

Control of internal parasites.—The Michigan station has developed a colloidal suspensoid state of iodine which appears to be not only ideal for disinfecting poultry houses, sow-farrowing pens, and the like, in a 0.2 per cent suspension in water, but is also a highly efficient vermicide for the treatment of stomach worms of sheep and intestinal worms of poultry when administered in connection with some vehicle for carrying iodine to the worms, such as milk and Epsom salts.

Stomach worms of sheep are, according to the Connecticut Storrs station, more effectively controlled by iodine (Lugol's solution) than by tobacco dust, nicotine sulphate, or copper sulphate. The iodine solution kills both the mature and immature worms. It can be used to kill the immature worms in lambs and pregnant ewes if necessary, but it is better to treat pregnant animals early in pregnancy, unless they show marked symptoms of stomach worm infection. The treatment used was drenching lambs over 30 pounds in weight with 4 ounces of a solution made by adding 0.5 ounce of Lugol's solution to 1 quart of water and repeating this treatment once every 4 weeks. For older sheep each animal was drenched with 4 ounces of a solution of 1 ounce of Lugol's solution in 1 quart of water and repeating the treatment at 4-weeks intervals from June to November, inclusive.

Anthrax.—The Louisiana station found anthrax spores in various parts of plants growing on infected soil, thus indicating that such plants may be carriers of the disease.

Poisonous plants.—White snakeroot, *Eupatorium*, is reported by the Illinois

station to be a common cause of what is known as trembles in cattle, horses, and sheep in the Mississippi Valley. The plant generally grows in woodland pastures, reaching maturity in August and September. The trouble generally appears during late summer and autumn especially when other vegetation is scarce because of drought. Horses, cattle, and sheep grazing in pastures where white snakeroot is found may be fatally affected. The plant is occasionally fatal to man, and in case of recovery there is a long period of convalescence and often lasting debility. Pastures known to be infested with the plant should not be used for animals during the late summer or fall. It can be eliminated from pastures by persistent pulling every year.

The wild chokeberry was found by the Nevada station to contain hydrocyanic acid in fairly large quantities. Range losses from this plant are confined to cattle and sheep. It is eaten only when there is a shortage of other vegetation, and losses are most common, therefore, on overgrazed areas. The leaves are most poisonous during spring and early summer, heaviest losses occurring at this time. Animals do not develop a tolerance for the plant, and no effective remedy has been found.

In feeding experiments with dried material of *Lupinus argenteus*, the Wyoming station found that it took large amounts of seeds and pods to produce any toxic effect on sheep. Three pounds of seed or 4.4 pounds of the pods per hundredweight was required to produce serious symptoms, and under ordinary conditions the sheep would not eat enough to produce harmful effects. The lupine was found to contain an oily substance more deadly than the crystalline alkaloids.

FOODS—AGROTECHNY

Composition and nutritive value of corn.—The Illinois station made a notable contribution to the subject of foods during the year in the publication of a bibliography of work on the composition and nutritive value of corn and its products. The extent of investigation on the subject is indicated by the fact that the bibliography occupies nearly 150 closely printed pages. A large proportion of the references is to American work.

Wheat flour and bread.—Factors affecting the milling and baking quality of wheat flour are being studied by a number of stations. Some recent station contributions to this subject are as follows:

The North Dakota station found a positive correlation between protein

content of wheat and the percentage of dark, hard, and vitreous kernels and the baking quality of the flour and between test weight per bushel and flour yield but not loaf volume and absorption.

Cool storage of wheat for two years showed no harmful effect on loaf volume or baking quality, and possibly an improvement, in experiments at the North Dakota station. There was some deterioration in warm storage. The Utah station found that highly milled flour made from sound wheat could be stored in dry rooms free from odors for at least four years without deterioration, but that low-grade flour and that made from whole wheat deteriorated under the same conditions during this period. The bread making properties of flour increased for a time in storage. The percentage of soluble amino nitrogen decreased. The moisture content of the flour as well as of the wheat tended to approach a constant of 8 per cent. Water-soluble phosphorus increased during storage, due apparently to cleavage of the phospholipins of the flour. Soluble carbohydrates increased, whereas acidity decreased at first but later increased. The rate and extent of increase varied with the flour, being more rapid and greater in poor grade flours than in high grade.

Milling was found by the Utah station to remove 70 per cent of the ash, 63 per cent of the calcium, and 79 per cent of the magnesium of wheat. The calcium-phosphorus ratio in the wheat was 1 to 2.2 and in the flour 1 to 3.8.

Yeast fermentation of doughs was accelerated by the NH_4 ion and by phosphates, in experiments reported by the Minnesota station. Very small quantities of the aluminum ion were found to be very effective in increasing the capacity of the dough to retain carbon dioxides. Wheat sprouted for three days under controlled conditions and added to flour increased its diastatic activity and improved the baking quality. Lactic and acetic acids were the only organic acids found in flour preparations fermented with yeast, lactic acid to the extent of about 75 per cent of the organic acids present, and acetic acid 25 per cent.

Proteins of cereals.—The Minnesota station found the prolamines from emmer, einkorn, spelt, and durum to be closely related to gliadin and glutenin from wheat, those from teosinte and kafir to zein from corn. The former appeared to be more closely related to gliadin than to glutenin, while the protein from teosinte was more closely related to

zein than was that of kafir. No reactions were obtained between antisera for the corn group with proteins from the wheat group, and conversely. A simple, accurate, and direct method for the preparation and quantitative determination of glutenin in wheat flour which may also be applicable to the study of the glutelins of other cereals and so be useful in determining their bread making qualities.

Food value of grain sorghums.—The grain sorghums are largely used as food in certain parts of the world. The Oklahoma station found in experiments with rats that grain sorghum seed sustained life and appeared to contain a sufficient amount of food accessory substances. The protein substances, however, are nutritionally incomplete.

Food quality of potatoes.—As a result of analyses of several hundred carefully selected individual potatoes, the Colorado station found no two of identical composition in the same variety, in the same group, or even in the same hill. The quality of the potatoes appeared to depend "more upon grower, soil, and season than upon variety." Steamed or baked potatoes were found to contain less water and consequently more of the other constituents—carbohydrates, nitrogenous matter, and ash—than boiled.

Edible canna starch.—Manufacture of starch from the edible canna has been shown to be practicable by the Hawaii station. The canna starch is characterized by exceptionally large grains and hence is recommended for infants and invalids. Morphologically it is similar to potato starch. "When cooked it forms a semitranslucent, rather sticky mass, such as is characteristic of potato or arrowroot starch but different from the opaque gel obtained from corn-starch."

Deterioration of sugar.—The Louisiana station showed that by protective inoculation of cane sugar with torulae not only was the keeping quality greatly improved but there was also great improvement in the color as well as the physical condition of the sugar crystals. Treated sugars were much less hygroscopic than untreated, owing to loss of levulose and lost moisture in storage, whereas untreated sugars absorbed moisture. Sugars having a torulae content of 1,000,000 per gram of film did not deteriorate.

Jelly making.—The enormous waste of surplus fruits has led to widespread efforts and to find more efficient and profitable ways of utilizing this surplus. One of the means receiving much at-

tention by both the Department of Agriculture and a number of the experiment stations is jelly making. The Colorado station published during the year a comprehensive bulletin on the making of fruit jellies, based on extensive investigation, which describes the methods necessary to secure jellies of assured quality and standard grade.

The Delaware station, studying more in detail the factors controlling the jellying of fruit juices, found that, other factors remaining constant, the strength of jelly is dependent upon its pH value and not upon total acidity. The strength of jelly at the optimum pH value varied with the kind of acid used. With a given quantity of pectin and acid the optimum strength point was determined by a rather definite amount of sugar. Increasing the sugar beyond this point decreased strength, and decreasing it increased toughness. The point of optimum jelly strength was reached when the amount of sugar used formed a saturated solution, the amount of pectin and acid remaining constant. For a given quantity of pectin and sugar at a constant pH value, the strength of the jelly increased with the concentration of pectin. The strength of jelly decreased consistently with the time of boiling the pectin-acid solution before the addition of sugar but varied only slightly with the time of boiling the pectin-acid-sugar solution. The strength decreased with increase of temperature and increased with age. Regardless of total acidity or presence of salts, the minimum point of jelly formation occurred at a pH value of from 3.50 to 3.35. The optimum point of jelly formation varied between the limits of 2.85 and 3.30, depending upon the nature of the acid and salt used. Total acidity may vary over a wide range, depending upon the buffering power of the initial solution from which the jelly is made. The strength of the jelly, made by adding a salt to the pectin-acid-sugar solution, was found to be dependent upon the initial pH value of the solution and the concentration of the salt.

A method of determining pectin by titration of the acidity developed on saponification with sodium hydroxide was reported by the Missouri station. This is based upon the fact that under constant conditions the amount of pectin is proportional to the acidity developed. Electrometric titrations of pectic acid precipitated by hydrochloric acid from the saponified pectin showed 11 carboxyl groups, but apparently saponification

was not complete, since the composition of pectin as shown by combustion indicated 12 such groups. On the basis of 11 free carboxyl groups and 1 unsaponified group the molecular weight of pectic acid is estimated to be 2,138.

To get the clear pectinous fruit juice necessary for a brilliant clear jelly of desirable consistency the Oregon station found that the fruit should be parboiled at a temperature not exceeding 212° F., to increase the solubility of the pectin, and the juice extracted under pressure while still hot. Juice obtained with heat and pressure was found to be richer in pectin than that which flowed off freely. Filtration with the addition of clarifying agents and under pressure if required was necessary to obtain a clear juice. Concentration in vacuum is recommended for juices that are to be stored.

Concentrated fruit juices.—Concentration in vacuo was found by the California station to be the most practical method for concentrating fruit juices, although concentration by freezing preserved the color and flavor of the fresh juice better. It did not, however, yield so high a concentration as vacuum concentration. It was found that the aroma of the fresh juice lost during concentration could be recovered from the condensate by redistillation and returned to the concentrate. Excellent concentrates were made from the juice of oranges, lemons, grapes, pomegranates, apples, raspberries, and loganberries, and other blackberries. Strawberry concentrate lacked color, but it was possible to make up this deficiency by the addition of blackberry concentrate. This station also found that juice concentrated in vacuum at a low temperature retained practically all of the antiscorbutic value of the original juice. Clarified concentrated orange juice retained this factor to a great extent, although it is probable that the longer exposure to the air at higher temperatures lowered it somewhat. Desiccated orange juice prepared by a spray-drying process retained a good proportion of the antiscorbutic value even after two years' storage. A dried whole orange product prepared in a commercial dehydrator proved to be a very concentrated source of the antiscorbutic factor. Concentrated lemon juice, commercially prepared by evaporation in vacuum at a low temperature, was also found to be a concentrated source of the antiscorbutic substance.

Sauerkraut.—Fermentation of sauerkraut, under ordinary conditions, is very variable and the product equally so. In experiments by the Wisconsin station

on controlled fermentation, it was found that inoculation with selected cultures of lactic acid bacteria altered the normal flora of the kraut and gave an improved product. It reduced the number of foreign organisms and the duration of their existence in the fermentation. The inoculated kraut contained more lactic acid and less acetic acid and ethyl alcohol than the uninoculated kraut.

Vitamin content of milk of silage-fed cows.—Milk from cows fed grain sorghum silage was found by the Oklahoma station to be superior to that from stover-fed cows and to furnish sufficient vitamins for rats and guinea pigs when fed at rates of 10 per cent of the body weight, indicating that the vitamins of the sorghum were not destroyed by ensiling.

Effect of light on eggs.—The Kansas station found that eggs from hens receiving a large amount of ultraviolet light contained an abundance of the antirachitic vitamin, while eggs from those receiving a limited amount of the light contained only a small amount of the vitamin. Eggs from hens given cod-liver oil at the rate of 0.5 cubic centimeter per hen per day hatched as well as those from hens receiving direct sunshine.

Blackening of canned corn.—It appears from studies made by the Illinois station that the blackening of canned corn is not wholly due to the container but may be in part due to the condition of the corn at the time of canning. Application of acid phosphate to the soil at the rate of 1,200 pounds per acre greatly increased blackening, while use of 600 pounds per acre of potassium chloride decreased it. High-protein and high-oil field corn blackened much more than low.

Spoilage of tomato pulp.—The New York State station found gaseous fermentation, which is responsible for considerable losses in stored tomato pulp, catsup, and other tomato products, to be due to an organism to which the name *Lactobacillus lycopersici* was given. "Laboratory tests indicate that a temperature of 150° F. (65° C.) for five minutes or one of 170° F. (76° C.) for two minutes destroys the organism in catsup. Slightly longer exposures were needed in pulp. The organism is practically always present under factory conditions but is normally eliminated by proper processing."

Canning in acid brines.—In a study of the rôle of acidity in vegetable canning, the California station found that brines acidified with a small quantity of citric acid greatly reduced the heat resistance of the spores of heat resistant bacteria

and that if the decrease in pH value which occurs during heating is taken into account it is possible to sterilize canned vegetables much more easily in acidified brines than in nonacidified brines.

Botulism poisoning.—The Colorado station found that the organism *Clostridium botulinum*, causing botulism poisoning, is widely distributed in soils in form of spores which are highly resistant to heat. Strains of the organism were found whose spores were not killed by boiling for three hours at 212° F. Occasionally even more resistant forms were encountered, for example, one of which the spores were not killed by six hours' boiling at the altitude of Denver, Colo.

AGRICULTURAL ENGINEERING.

Notable progress was made at the stations during the year in the development of investigation in agricultural engineering.

MACHINERY

Tractors.—The California station found, in a continuation of its studies on the removal of dust from tractor engine intakes, that at least 90 per cent of the dust normally inspired by an air cleaner or carburetor could be avoided if the intake was placed high and faced away from the direction of motion of the tractor. A rearward opening acted as an inertia type dust separator. It was further found that in a service test involving several uncontrollable variables, no just comparisons can be drawn among air cleaners not differing greatly in efficiency. Frequent changing of crankcase oil and consequent maintenance of higher viscosity markedly reduced engine wear.

A method of determining the distribution and value of tractive impulse stresses in soils as delivered by the lug of a tractor drivewheel has been developed by the Alabama station. In this method the soil is placed in a box in uniform, evenly compressed layers, separated by sheets of very thin paper treated so as to offer a minimum resistance to shear. The layers are placed perpendicular to the soil surface and at right angles to a plane passing through the center of the entire rim of a lugged tractor wheel. The soil block is then placed in a testing machine and the wheel is run forward until the lug has passed through any desired amount of soil. The block of soil is then removed from the machine and the surface, lug imprint, and each successive layer of the soil is cast in plaster of Paris. Thus the entire soil block is accurately cast

into component blocks, the surfaces of which conform to the distortions produced in the sheets of delicate paper by the tractor wheel lug. These casts are accurately marked into contours of equal distortion or pressure. The relative thicknesses of the casts at any point give a measure of the pressure at that point and the entire soil movement under impulse stress is visible and in a permanent form for study.

Plow draft.—Heavy manuring of silt-loam soil seemed to increase the draft of plows slightly in experiments reported by the Missouri station. Chemical fertilizers, even in heavy applications, did not increase the draft. Within a range of moisture conditions satisfactory for plowing there was a tendency for the draft to increase as the moisture content decreased.

The plow draft on different soil types varied with different soil treatments in experiments at the Illinois station. The addition of organic matter to a soil tended to reduce the power required for plowing.

Disk harrows.—By the proper arrangement of gangs, the California station found it possible to obtain a disk harrow which tills a strip of land, the center of which is offset from the center of the tractor as is required in orchard cultivation. Such a harrow, while operating off center, does so without side draft upon either the harrow or the tractor. Only one position behind the tractor was found where a given disk harrow, operating under specific conditions of gang arrangement, weight, speed, and soil, can do so without side draft. It was also possible to design a disk harrow in which the gang arrangement can be adapted to operation, without side draft, either directly behind the tractor or with a large right or left hand offset.

Plow metal.—Studies by the Alabama station suggested that the adhesion of soil to plow metal is due to the fact that the two materials are brought into such close contact as to permit the molecules of one substance to attract those of the other. Some indications were obtained that certain treatments of the metal materially affected the adhesion.

Draft of wagons.—The Missouri station found that the draft in pounds per ton of load of various kinds of equipment with different heights of wheels and widths of tires averaged the greatest for a cornstalk field, followed in order by muddy clay road, spongy clay road, bluegrass sod, burned clay or ballast, dry well-packed cinders, dry and firm clay road, dry packed macadam, dry well-packed gravel road, worn brick,

concrete in good condition, and new brick. Tests in cultivated land showed a saving in draft per ton of load by increasing the height of the wheels and the width of tires. The wagon with high wheels and narrow tires had about the same draft as the common low wheel, wide tire wagon. The convenience of the low-wheel wagon was taken to indicate its desirability for farm use. Neither the wheel height nor the tire width markedly influenced the draft on hard surfaced roads.

Silo fillers.—The Wisconsin station has developed a formula which indicates the maximum capacity of silage cutters with reasonable accuracy. Silage cutters were found to have much greater capacities than is ordinarily attributed to them. Machines with 18 or 20 inch cylinders were found to have much more capacity than any ordinary crew of men can supply. This was taken to indicate that larger machines are unnecessary, and that machines of these sizes can be operated at speeds approximately 40 per cent slower than at present recommended and still have sufficient capacity for ordinary requirements.

Threshers and harvesters.—Studies of the efficiency of grain separators by the Illinois station showed that man labor is used more efficiently with basket racks and with small threshing rigs. Blanket tests on 20 machines showed that the grain loss could be reduced below 1 per cent by proper machine adjustment and better feeding except where the loss was caused by damp grain. The Utah station found the losses from 12 harvester threshers surprisingly low. In most cases the loss from headers equaled that from combines, and in addition the stationary thresher gave a loss of about 1.75 per cent.

A thresher for single heads of grain for laboratory use in plant breeding work was developed by the California station. In this the threshing cylinder is mounted directly on the motor shaft. No toothed concave is used, thus making it possible to use higher tooth tip speeds without cracking the grain. Sloping bars are inserted in the housing to prevent any possibility of whole heads being blown by without being hit by the cylinder teeth. The threshing cylinder and its teeth constitute the only blower, and the blast is entirely adequate to remove the chaff.

Seed wheat treating machines.—Studies at the Oregon station on mechanical equipment for the treatment of seed wheat with copper carbonate dust resulted in the development of a diagonal axle machine using a barrel or steel drum for a container, fitted with a mix-

ing board placed diametrically across the barrel two-thirds of the way back from the door. It was found that in treating machines of this type the mixing action will cease and the grain will be held against the drum walls by centrifugal force at from 48 to 50 revolutions per minute. This maximum speed was not influenced by the quantity of grain in the drum. The best speed of operation was found to be about 30 revolutions per minute. A microscopic examination of the grain at each tenth revolution showed that at 10 revolutions each grain was coated, but rather unevenly. At 40 revolutions the coating of dust was complete, smooth, and even. Any further turning merely smoothed out the coating. The conclusion was drawn that the sliding and rolling action of the grain in this type of machine is very effective in giving a quick and even distribution of dust in an adhering coat.

The most common fault of the seed wheat treating machines used in the State was found by the California station to be their inability to prevent the escape of dust into the air. Every batch mixer tested coated the seed satisfactorily if operated long enough. The most efficient quantity of grain to use at each treatment in a batch mixer was found to be that equal in volume to from one-fourth to one-third of the volume of the mixing box. A rotary barrel type churn was found satisfactory when filled about one-fourth full and turned slowly. It was necessary for the grain to fall from end to end or from side to side of the churn in order to obtain the best results. A tight box mounted on a shaft and revolved slowly by hand or mechanical power was also satisfactory. Batch mixers were found to be in general of too small capacity and to require too much labor to be satisfactory for warehouse and ranch use.

In general, it was found that the design of the interior of the continuous revolving mixers may differ very widely, with a correspondingly wide difference in effectiveness. The results indicated that the baffles should be so placed as not to hinder the outflow of the treated grain too much, and that the height of any baffle should not exceed one-sixth of the diameter of the revolving cylinder. The speed of operation which required the most power and produced the most violent tumbling about of the grain gave the best results.

Continuous gravity type mixers were found to require less of the coating material than most other types. The capacity depended upon the width,

breadth, and height of the vertical chute. It was necessary for the slope of the inclined baffles to be steep enough to cause the grain to fall readily and the machine to clean itself completely. Dusted grain lodged on a much steeper slope than untreated grain. When a proportioning device was used the feed of dust was found to be irregular and the coating of the grain not uniform.

Seeding machines.—The California station found that, with the same setting of the seeding indicator on several types of grain drills, the quantity of seed in the hopper did not affect the rate of seed delivery until the seed shells were exposed. Neither the operation or nonoperation of the agitator nor variations between ordinary high or low field speeds had any effect on the rate of seeding. There was considerable variation in the rate of seeding of different varieties of wheat. The treating of wheat with copper carbonate dust caused the rate of seeding to decrease from 5 to 37 per cent, depending on the variety and quality of the seed. Large plump varieties gave the largest decrease in rate of seeding when treated with copper carbonate dust, especially when planted at low rates per acre.

STRUCTURES

Crop storage.—The Illinois station found that tile ventilators were slightly more satisfactory than A-frame ventilators in cribs 8 feet wide and 10 feet high containing corn with 43 per cent of moisture. The most economical method of drying corn with forced air was found to be that in which unheated air is blown into a special ventilator in the center of an open crib.

The temperatures inside an apple storage house, with no means of mechanical refrigeration or heating, tended to follow prolonged outside conditions, in experiments at the Indiana station. The humidity of the air of the storage rooms was easily maintained at approximately 90 per cent saturation, with 80 per cent as a minimum, regardless of outside changes. Temperatures could be reduced by natural draft to as low a degree as by forced ventilation, but not so quickly.

The main problem in the development of common storage for eastern apples is, according to the Massachusetts station, to provide some means for producing and maintaining temperatures as low as 40° F. or less in cellar storages in the early storage season. This was accomplished by the use of ice either with or without salt to hasten the cool-

ing and either with or without insulation against ground temperatures, as was found necessary.

Sweet potatoes can be kept in excellent condition in adobe storage houses until late in the spring, according to the Arizona station. The advantages of the adobe storage house were found to be cheapness of material, simplicity of construction, and high insulating properties.

Poultry houses.—The Iowa station found that the ventilation of poultry shelters is primarily a winter problem in which relatively low temperatures must be considered and in which excessive humidities must be dealt with instead of the low humidities existing in human shelters. Comfort is maintained when the heat produced by normal body combustion approximately balances the radiation necessary to maintain a fairly constant body temperature. Extremely low temperatures were found to reduce egg production, whereas high temperatures accompanied by excessive humidities caused discomfort, inactivity, and loss of appetite, and increased the susceptibility to bacterial invasion. Indications were noted that air purity as measured by carbon dioxide content is probably secondary in importance to temperature, humidity, and rate of air movement.

Egg production in a house heated with a brooder stove exceeded that in an unlined, fully ventilated house, and the increased production exceeded the cost of heating, in experiments reported by the Nebraska station. A house which was lined but unheated gave almost the same egg production as the heated house. Lack of ventilation during the night did not appear to affect the egg production adversely.

Livestock shelters.—Investigations at the Iowa station on masonry arch barn construction, involving the design, construction, and testing to destruction of a 36-foot reinforced concrete and clay block arch with a rise of 24 feet 7 inches, showed that the arch as designed on the basis of available structural principles was much stronger than required. The stress required to cause failure was equivalent to the pressure created by a wind velocity of 160 miles per hour. The results indicated both the possibility and practicability of building a barn wholly of masonry.

Silos.—Studies at the Iowa station to develop a satisfactory treatment for making silo walls impervious showed that bitumen or asphalt applied so as to insure a good bond was the most satisfactory treatment. All attempts to use plaster coats of various kinds

were generally unsuccessful. Silo storage capacities were found to vary widely from year to year, due primarily to differences in the water content of the silage and to a less extent to the weight of the grain.

Dairy structures.—Investigations at the California station on milk houses for California dairies indicated that concrete is an ideal material for the foundations and floors, all floors to be laid on a well-drained surface at least 4 inches above the ground level. It was found inadvisable to have an outside entrance to the milk room but to enter from a vestibule or wash room in order to prevent the entrance of flies. Window glass surface equivalent to 10 per cent of the floor area is considered sufficient to admit the necessary sunlight.

IRRIGATION

Soil moisture capacity.—The Washington station found that the water holding capacity and rate of water penetration in six soils were very uniform. These soils held as much as 3.5 inches of water per foot of depth when saturated in the field and 2.5 inches per foot under conditions of equilibrium after being thoroughly irrigated. This indicated that the upper 6 feet of soil will hold 15 inches of water before any loss by percolation occurs. It was further found that the soils must contain 0.5 inch per foot in order to have any water available for crops. Irrigation of from 2 to 3 inches every 20 days was necessary to keep them restocked with water during the irrigation season where there were no crop demands.

In the determination of the moisture equivalent, the California station found that the smaller the sample the larger the percentage of water retained. Some clays were found to become impervious to water during centrifuging when the quantity of soil placed in the centrifuge cup was increased, and these soils reabsorbed the supernatant water when the centrifugal force was relieved. The moisture content was found to increase from the inner to the outer surface of a 60-gram block of soil, but the rate of increase was lower than that resulting from reducing the size of sample from 60 to 5 grams. The apparent specific gravity of a 60-gram block of soil was found to be significantly greater than that of a 10-gram block, and decreased continuously as the size of sample was decreased from 60 to 10 grams. The apparent specific gravity within a 60-gram sample increased significantly from the inner surface outward to a

point about 6 millimeters within the sample, beyond which it remained substantially constant to the outer surface. The placing of weights on the inner surface of 5-, 10-, 20-, or 30-gram samples decreased the quantity of water retained. Subjecting the soil to centrifugal force until the moisture was in equilibrium resulted in the establishment of an equipotential region throughout the block of soil. In general, it was found that the average pore space did not limit the quantity of water retained by the soil block.

Water losses.—The Colorado station showed that under still air conditions the rate of evaporation decreases as the difference between the temperatures of the air and water increases. The maximum rate of evaporation was found to occur at about sunrise in the laboratory and during the afternoon under fully exposed conditions.

Soil mulch had an inhibitory effect on moisture absorption, in experiments at the Washington station, when individual rains were not of sufficient volume to fully penetrate the mulch. This was due to increased evaporation of the newly fallen rain. There was a greater total loss of moisture from mulched soil when conditions favored evaporation than from unmulched soil.

A correlation between ground-water supply and the transpiration losses in a cottonwood and mesquite forest under different conditions of temperature, humidity, and cloudiness, and stages of leaf growth was observed by the Arizona station. The daily fluctuations of the water table caused by the transpiration of trees and by recharge of the water supply were large, sometimes exceeding 5 inches.

Duty of water.—The California station failed to correlate the use of water by prune trees with any particular percentage of available soil moisture. On the contrary, a continuous need for available moisture from the beginning of spring activity to dormancy in the fall was indicated. Depth of ground water below the soil surface must apparently be considered along with other factors in fixing the economical field duty of water. Widely varying the time and amount of irrigation was found to have no appreciable effect on the root development of alfalfa receiving uniform total applications of water.

Irrigation pumping.—Tests of fuel oils for pumping by the Arizona station showed that under the new process of cracking the crude oils now used by some refineries, the volatility of California cracked oil distillates is higher in relation to their specific gravities than that of

straight-run distillates. The cracked oils appear to have the same qualities as straight-run oils of 3° B. higher gravity.

Irrigation structures.—Studies of the Venturi flume at the Colorado station showed that with the 1-foot flume a marked degree of submergence is possible before the discharge is reduced from that of the free flow due to the formation of a hydraulic jump within the structure. It was found that the degree of the resistance to submergence increased as the width of the throat increased. The allowable degree of submergence was from 70 to 75 per cent for the smaller flumes and from 75 to 80 per cent for the larger sizes.

Alkali soil treatment.—Black alkali was found by the Arizona station to resist leaching tenaciously, and could be removed from the soil successfully only after neutralization. The percolation of water through very fine sand or fine sandy loam soil was accelerated by gypsum treatment. The acceleration increased with the amount of gypsum applied, at least up to double that necessary to neutralize the black alkali present.

Leaching alone was effective in removing the neutral salts from impervious black alkali soils, in experiments at the Oregon station, but was not effective in removing sodium carbonate or in improving the physical condition of the soil. Leaching and drainage in connection with chemical treatment were necessary in order to remove the neutral salts resulting from the decomposition of sodium carbonate. The value of heavy gypsum, sulphur, and alum treatments was indicated.

DRAINAGE

Ground-water level.—Studies of ground-water level by the North Carolina station showed that the character of the soil rather than topographic features is the determining factor in the rise and fall of ground-water levels under similar drainage conditions. The ground-water level between tile lines in a level soil of uniform texture was found to rise in a smooth curve from the tile lines to a point midway between them. This curve may be very irregular in a soil of irregular texture. The rate of drop of the ground-water level midway between tile lines at a 3-foot depth in Norfolk sand averaged from 1 to 1.7 feet per day in the surface foot and from 0.5 to 0.75 foot in the second foot. The ground-water surface between the widely spaced drains commonly used in muck soils was found to be compar-

atively flat, and the rate of drop below the surface 18 inches was very slow.

Run-off.—Gaugings made by the North Carolina station on a typical dredged Piedmont creek indicated that the drainage factor used in computing channel sizes for drainage improvements of this type should be increased to 1 inch per 24 hours as compared with 0.5 to 0.75 inch per 24 hours formerly used. The ratio of run-off to rainfall was found to vary from 33 to 54 per cent, with an average of 45 per cent.

Records of discharge from farm tile drainage systems obtained by the North Carolina station indicated that a run-off coefficient of from one-third to three-eighths inch per 24 hours will give satisfactory results under average conditions of soil and spacing of laterals. Where surface water inlets are used, this should be increased to 0.5 inch. It was further found that a 1-inch rainfall will be absorbed by an open soil drained by tile to a depth of 3 feet without any run-off where the groundwater surface is at the level of the drains prior to the rain.

Drainage structures.—In experiments on the maintenance of drainage canals in the Coastal Plain, the North Carolina station found that where the depth of water in the canals was considerable throughout the year there was little growth in the channel. Where the canal was large for the quantity of water carried, resulting in a shallow normal depth of flow, conditions were favorable for a heavy growth of vegetation. The most favorable season for clearing the channel of plant growth was found to be between June 15 and August 1.

A spacing of 120 feet with a depth of 3.5 feet may be used for the more open Coastal Plain soils, according to the North Carolina station, with the same beneficial results and a saving in cost over a spacing of 100 feet with a depth of 3 feet. Silt was not deposited in 4-inch laterals when laid in a sandy clay subsoil on a 0.3 per cent grade. Experiments in substituting tile of large diameter for open ditches showed that tile sizes up to 18 inches in diameter are practical when supplemented by a sufficient lateral system and surface water inlets.

Drainage by pumping.—Investigations by the California station showed that the cost of drainage of irrigated lands by the pumping method compares favorably with that of any other method yet tried. More effective drainage was possible by the pumping method than by the use of tile or open drains, because of the flexibility of the pump-

ing system and the greater depth to which it is economically feasible to lower the water table. The pumped water was found to be readily available for irrigation and to compensate in part for the cost of drainage by this method.

SANITATION

Sewage disposal.—Studies by the Illinois station of the design of farm septic tanks showed that the two-chamber tank yields the purest effluent. Better digestion of solids, as indicated by sludge accumulation and solids passing out, was also obtained in this tank than in single or three-chamber tanks. A 48-hour retention period was found to be superior to the 24 and 72 hour periods.

In a continuation of studies on the biology of sewage disposal, the New Jersey stations observed a rise and then a fall in sludge digestive activities in Imhoff tanks. High amounts of ammonia were found to correspond with low percentages of carbon dioxide production. The carbonates reached the peak shortly after carbon dioxide and ammonia. There was in general an inverse relation between carbon dioxide production and H-ion concentration. Apparently the H-ion concentration gives a true index of the total activities taking place in a tank. Different types of digestion appear to dominate at different times in Imhoff tanks. Indications were obtained that the protozoa of Imhoff tanks may afford a fair criterion as to proper working conditions.

An apparent relation between the total bacterial numbers, total animal life, percentage of carbon dioxide in the gas, and the pH values of the effluent of Imhoff tanks was observed by the New Jersey stations. When the tank liquid registered a pH value below 7, the solids rose and foaming occurred, when it rose slightly above the neutral point the foaming subsided and the scum receded. Fresh solids, contaminated with partially digested material, were found to pass through a course of digestion similar to that of uncontaminated fresh solids, there being, however, a marked difference in the rapidity of digestion.

A seasonal fluctuation of fungi, which reached a maximum during the winter months, was observed in sprinkling filters at the New Jersey stations. Film removal studies showed that, when this process started, several species of protozoa increased rapidly in numbers, there being apparently a succession of groups. When fungi became more

abundant the large numbers of free-swimming protozoa disappeared.

Water supply.—The Colorado station found distillation to be the only method by which alkali water may be satisfactorily purified for drinking purposes. It was possible to distill such water from 10 to 15 per cent cheaper with coal than with artificial gas.

A well may be safely located from 50 to 100 feet from a privy vault, cesspool, septic tank, or sewer line in ordinary soil, according to the Illinois station, but a greater distance may be required in gravel, sand, or open soil. Gravity water supply systems were found to be satisfactory for many farms, although apparently the hydropneumatic system is more generally satisfactory. Studies of different types of electric water systems indicated that the actual efficiency of such equipment is low, and that many could be operated with greater economy. It required from 15 to 25 per cent more power when the range of working pressures was from 20 to 50 pounds than when it was from 10 to 20 pounds. The latter range was found satisfactory under practically all conditions.

POWER

Use of electricity from central stations.—Investigations of the electrical hatching of chicks by the Oregon station showed that the power was on for only very short intervals of time in each individual incubator. The power utilization during the first day was relatively high on account of the initial heating of both the incubator chamber and the eggs. The daily consumption then remained constant at 4 kilowatt hours per day until the fourteenth day, at which point it decreased, due to the utilization of the latent heat in the egg by the growing germ. From that time on until the chick was hatched the power consumption gradually decreased, reaching a low point of 1 kilowatt hour per day at a room temperature of 65° F. The room temperature was found to materially affect the power consumption and should not exceed 95° in order to obtain economy of time in the egg cooling process. An average temperature of from 85 to 90° proved to be the best. Ventilation became inefficient in the incubators tested when the room temperature was raised to 85 or 90°.

The electrical energy required to run milking machines in seven dairies was found by the California station to vary from 0.033 kilowatt hour to 0.145 kilowatt hour per day per cow, and from 0.16 to 0.5 kilowatt hour per 100 pounds of milk.

The average number of farm users of electricity per mile of distribution line in 10 representative areas of the State was found by the Oregon station to be 4.17, the most extensive use being for lighting and household conveniences. It was concluded that the cost of electricity per kilowatt hour will depend largely upon the volume of use, and that aside from household appliances, pumps, and some dairy machines, the agricultural equipment at present available is not adapted to the electric drive.

The greatest appreciation of electric service by Kansas farmers is for illumination according to the Kansas station. The demand for the electric brooder on farms appeared to be wider than that for the electric incubator. The use of electricity for pumping was found to offer greater promise of building up a rural electrical load than any other single service. Grain binding, elevating, shelling, and cleaning appeared to offer the best field of general farm development in motor belt work, while ensilage cutting and threshing if generally motorized must compete with the tractor. Possibilities for a general utility motor were indicated, but the use of electric motors for drawbar work was considered to be as yet wholly in the experimental stage. Electric milking machines were also found to be in the developmental stage, particularly for the smaller dairy farms. The average farm user of electricity consumed but little, if any, more current than the urban user, and line and transformer losses on many rural lines exceeded the amount of current used.

The best method of bringing electric service to the farm is, according to the Minnesota station, that in which the lines are built by the public utility and paid for by the consumer on an actual cost basis, with due consideration for degree of benefit obtained. It was further concluded that service charges should be based on a low rate with a fixed minimum charge.

Individual electric plants.—A home-lighting plant propelled by wind investigated by the Indiana station had a capacity to produce an average daily output sufficient to light the average farm home and also to operate such appliances as a sewing machine or vacuum cleaner.

The cost of electric current from isolated farm electric plants was found by the Virginia station to be exceedingly high. It appeared that, over a period of time, the cost of current from the non-battery type of plant is lower than that from the battery type.

A fuel economy test by the Missouri station on a typical nonbattery automatic light plant showed that there was very little difference between the cost of operation for a small load and that for a large load, and that if the plant is operated at all, lights as large as from 150 to 200 watts might just as well be used.

MATERIALS

Binder twine.—Tests of binder twine by the Indiana station showed that the average tensile strength for most of the brands tested was above the guaranty, but that lack of uniformity in both tensile strength and thickness of the twine was the cause of breaks. The tensile strength was found to be directly proportional to the number of fibers in the twine and the number of fibers was of greater importance than their length. It was further found that the thickness of binder twine is not always an indication of its strength, since loosely twisted twine allows fibers to slip, causing the stress to be carried by individual fibers.

Concrete.—In cooperative studies with this department on the effect of immersing concrete and sand mortar cylinder specimens for one year in lake water containing from 2.34 to 4.72 per cent of a combination of magnesium and sodium sulphates, the Minnesota station found that none of the high alumina cements used showed evidence of any deterioration. None of the standard Portland cement cylinders cured in steam at a temperature of 212° F. showed any surface action of the lake water, regardless of the length of time they were so cured. Curing in water vapor at temperatures of 155 and 100° was found to be of no value. Considerable deterioration was evident in all cylinders cured in the laboratory in the moist closet, followed either by further curing in water or by storing in air, or both.

Beet pulp was found to have a destructive effect on both mortar and concrete by the Colorado station. This was not great up to 150 days of pulp storage, but increased progressively for longer periods.

Roofing materials.—Studies of the durability of prepared roofing by the Iowa station indicated that exposure to the sun is one of the most important deteriorating factors.

The tensile strength of bituminous materials was found by the Alabama station to decrease markedly as a rule after exposure to the weather for one year. The time required to break

down under a flame test also decreased in the majority of cases after exposure, although the sheathing surface appeared to retain its resistance to heat better than the weathering surface. However, exposure to the weather seemed to increase the temperature at which flowing began. Exposure seemed to decrease the tendency to absorb moisture, but to increase the volatility.

Fence posts.—The Missouri station found that setting wood fence posts in gravel and charring did not pay, and that painting with hot carbolineum was perhaps better than painting with creosote. Double tank treatment with creosote was the most effective, the 5-hour treatment being better than the 2-hour. It did not pay to treat some varieties, particularly honey locust, willow, cottonwood, and white oak, unless the whole post was treated. Black ash, sassafras, red oak, and ironwood made good posts if given the double tank creosote treatment. The Iowa station found that cottonwood, willow, and elm fence posts which were given a good creosote treatment 17 or 18 years ago are still in service and in good condition.

LAND CLEARING

Stone removal.—The Wisconsin station showed the mud-capping method of rock blasting to be entirely satisfactory for breaking ordinary rocks and boulders. The total cost of rock blasting was considerably higher when holes were drilled into the rock than when the mud-capping method was used.

Brush removal.—The Minnesota station found the average number of man hours required to "brush" an acre to be 32.4. Cutting brush in the late summer to prevent sprouting back was considered to be a practice of questionable value under ordinary farm conditions. It was found that sheep must be starved down to the pasture to do any real good from the standpoint of brush removal. The Alabama station found that the cost of brushing varies from one-half of the final cost in light timber to one-eighth of the final cost in heavy timber, and that in complete clearing the cost of brushing is about twice as great for pulling as for blasting.

To use a sprout mower, the Missouri station found that the stumps must be cut low so that they will not interfere with the machine frame or slow up the beater chains. The machine should be used the first year after the timber is removed, as second year growth is too large for effective operation. At least two stripplings per year are necessary.

Stump removal.—The Minnesota station found that stumps may be removed by blasting at least one-third more cheaply when the soil is full of moisture than when it is dry. Forest fires were found to be more effective than four years of decay in reducing stumping costs. Stumps that were dead, partially decayed, and burned were cleared with a smaller expenditure of man and horse labor than stumps that were green when burned. The cost of postfire clearing of stumps was only about half of that of prefire clearing.

The final cost per stump is about the same for pulling as for blasting, according to the Alabama station. The best results in blasting were obtained when the charge was placed at a depth of twice the diameter of the stump and 14 inches from the base. This was especially important in the case of stumps 15 inches and over in diameter. Other conditions being equal, the efficiency of blasting was found to be in direct proportion to the amount of free water in the soil up to the point of saturation. Best results were obtained in loosening stumps by blasting while under tension from the puller. Heavy blasting before pulling generally did not reduce the quantity of soil on the roots on removal.

ECONOMICS AND SOCIOLOGY

Adjustment of production.—A number of studies on the adjustment of agricultural production and its adaptation to market demands were reported by the stations during the year. A food consumption, production, and distribution survey of Charleston, W. Va., and its trade territory was reported by the West Virginia station, which showed soil and climatic conditions adapted to the production of potatoes and various truck crops, melons, fruits, meats, milk, butter, cheese, eggs, and poultry, for which there is a large demand in the local market. The importance of catering to the demand for products of higher quality than are now supplied the market is emphasized. A similar study was made by the Virginia station of local products consumed in the city of Roanoke. There is a growing demand at good prices for meat, dairy and poultry products, feed, truck crops, and fruit which can be grown to advantage locally. More efficient production, higher quality, and better adjustment to the market requirements are emphasized. A study of the present status and market outlet of fruits, truck crops, and poultry in Atlantic County, N. J., especially to supply the local market

demand, was reported by the New Jersey stations. Adjustment of production to market demand is somewhat restricted. Market facilities are improving and further improvement might be possible through adoption of a pooling system of handling the products. The advantage of growing a smaller number of better quality crops on each farm is suggested.

A study was made by the New Hampshire station of the present production, sales, and methods of marketing farm products of farms in Cheshire County, chosen as typical of changes that are taking place in agricultural production throughout a large part of New Hampshire and New England, which showed that the number of farms and the production are decreasing, and costs of transportation of food commodities are increasing. Except for the supply of whole milk, apples, bush fruits, and sweet corn, the county does not feed itself. Dairying is the basic farm industry. The average cost of feed for milk production on 40 farms with 5 or more cows per farm was \$1.49 per 100 pounds, or 60 per cent of the average price received at the cooperative milk plants. The advantage of permanent plantings of apple trees on favorable sites is indicated, as is also timber production. An expansion in the total acreage of vegetables is held to be inadvisable, although commercial potato production with machinery on 10 or more acres may prove profitable.

Economic studies of milk production.—Further reports on studies of dairy farming in New York were published by the New York Cornell station. These dealt with costs and returns in production of milk of different grades, on different farms, and under varying conditions of organization and management.

In a study of production of grade A milk, with and without cash crops, on farms in Chenango, Onondaga, and Cortland Counties, the average labor income of the farms without cash crops was \$299, on those with cash crops \$1,065. The cow cost of producing milk in the first case was \$2.59 per 100 pounds, in the second \$2.79. The cow costs per pound of butterfat were 72 and 80 cents, respectively. Outstanding features of some of the more successful farms were high yield of cows, high yield of cash crops, and intensive methods of management.

On farms in Madison County producing grade B milk with alfalfa roughage, the average net farm income in 1921 was \$997 and the labor income \$228, in 1922 \$783 and \$4, respectively. The net cow cost of producing milk in

1921 was \$2.50 per 100 pounds and in 1922 \$2.54. The cow cost per pound of butterfat was 74 cents in 1921 and 75 cents in 1922. In 1921 the average loss was \$19.87 per cow and 32 cents per 100 pounds of milk, but after all charges except those for labor were met the returns were 13.9 cents per hour for all time spent on the enterprise. In 1922 the average loss was \$20.65 per cow and 35 cents per 100 pounds of milk. The returns were 16.1 cents per hour for the time spent.

On 121 farms in northern Chenango and southern Madison Counties carrying 2,749 cows and producing grade B milk with cash crops and mixed hay roughage, the cow cost of producing milk was \$2.56 per 100 pounds. The cost per pound of butterfat was 76 cents, and the labor income per year was \$321. There was a loss of 46 cents per 100 pounds of milk produced. Some of the factors of success of the more prosperous farms were productive cows, economical feeding, and good prices for milk and cash crops.

In an economic study of the production of milk for factories making Limburger and whole-milk Cheddar cheese on 67 farms in Jefferson County, N. Y., the station found that the cow cost per 100 pounds of milk sold was \$2.45, while the average return was \$1.63, excluding calves, hides, and manure. The labor income was minus \$374. The farms on which this study was made are devoted almost exclusively to dairying. "Very few farmers in this area are getting ahead financially. Few farms are sold. The disappearance of hay markets with the coming of motor transportation has taken from these farmers their only cash crop. This means that the system of farming must be changed."

The low average returns from 22 dairy farms studied by the North Dakota station were found to be due mainly to the poor quality of the cows kept. Comparing two farms, otherwise similar, one of which kept scrub cows, the other good grade or purebred cows, it was found that the annual net income per cow was \$33 in the first case and \$68 in the second, the butterfat produced per cow being 146 pounds in the former and 300 pounds in the latter. The extra 154 pounds of butterfat was responsible for the profit of the second farm. If the latter had produced no more than the first farm it would have been operated at a loss.

Successful dairying in Vermont.—Of the factors which enter into the successful management of Vermont dairy farms, as indicated by correlation coefficients between the several factors and labor

income on 189 farms, the Vermont station found the most important to be quality of cattle and the economic employment of labor. On efficient management in these two respects rests largely financial success or failure. The station therefore emphasizes the importance of keeping only cows capable of large production and of giving careful attention to the planning and execution of the farm work.

Cost of beef production.—From a detailed study of the cost of finishing 1,558 steers for the market in the period 1913-1922 in Hancock County, Ill., the Illinois station found the average cost of adding 273.7 pounds of gain to be \$52.83. Marketing charges were \$2.87 per steer, and the finished animal, weighing 1,167.9 pounds, represented a total cost of \$124. The net selling price was \$113.90 and the net profit, allowing a credit of \$12.17 for by-products, was \$2.07 per steer. The results on different farms varied, however, from a profit of \$12.60 per steer to a loss of \$14.50 in the same year. During the 10 years covered by the study, feed cost was 85.5 per cent of the total feed-lot costs, man labor 4.1, and interest 4 per cent. General farm expense was 2.9 per cent, horse labor 1.81, buildings 0.82, miscellaneous 0.21, and death risk 0.66 per cent.

From data obtained from 23 farmers fattening 993 head of cattle, practically all the feed being home grown, the Minnesota station found that the cost per 100 pounds of beef laid down at the market varied from \$5.87 to \$9.37, and the price received varied from \$5.64 to \$10.36. The feeder who received \$10.36 for his beef made the most profit per head, and the one with a net cost of \$5.87 per 100 pounds laid down at the market made \$10.23 profit, which was more than the average. The feed required to produce 100 pounds of gain was 693 pounds of grain, 318 pounds of silage, 409 pounds of roughage, and 7 days of pasture. The labor to produce 100 pounds of beef was 0.27 of a man hour and 0.17 of a horse hour.

In a study of the cost of producing beef animals on California ranches during the period October 15, 1923, to February 1, 1924, the California station found that the costs of producing calves to the end of the first year after birth varied from \$22.47 to \$58.70, the average being \$38. The cost to the end of the second year averaged \$56.31, ranging between \$32.83 and \$88.04. The net cumulative cost of producing a steer to the selling period in the fourth year at an average age of 44 months was

\$108.69. The cheapest gains were made in the second year, the gains being relatively small thereafter. It is deemed most profitable to dispose of all beef animals before the beginning of the fourth year. Feed and labor, including management, constituted 59 per cent of the cost of raising a calf to the end of the first year, which increased to 67, 71, and 73 per cent, respectively, during the following 3 years.

Cycles in hog prices.—Studying the period from 1911 to 1924, inclusive, the Nebraska station found evidence of distinct cycles in hog production and prices. An unusual number of spring pigs were farrowed in 1907, 1911, 1915, 1918, 1922, and 1923. In December, January, and February following each of the large pig crops, an unusual number of hogs were marketed and hog prices fell. The number of spring pigs farrowed in 1909, 1913, and 1920 was below normal. The number farrowed in 1917 was much larger than in 1909 or 1913, but was considerably less than the average of the war-time period. Each of these small crops sold at a relatively high price per pound. Each period of good prices stimulated production. It is believed that a farmer may so regulate his own production that he will receive the advantage of the recurring periods of high prices, and that wisely regulated production and thoughtful marketing will go far toward stabilizing hog prices.

Cost of growing apples.—The Ohio station found the total cost per tree during a 10-year period to be \$5.69 for orchards under cover crop and \$3.35 for orchards under grass mulch, or counting only the trees living at the end of the period \$5.89 and \$3.75, respectively. The average income per tree for the period was \$6.51 for the cover crop orchard and \$6.91 for the grass mulched trees.

Cost of cotton production.—The more important factors which determine the yield and hence the cost and profits of cotton production were found by the South Carolina station to be mule and man labor for cultivation, fertilizers, and damage by the boll weevil. Yields of less than 200 pounds of cotton per acre cost about 7 cents more a pound than higher yields. Man and mule labor costs were correlated to a considerable extent with the acre cost of cotton, but on a pound and total production basis heavy use of labor usually paid. Analyzing the farm business as a unit, it was found that an average farm income of \$378 was obtained by the operators of the 333 farms included in the study. The owners made a higher farm income than the tenants. The average labor

income was minus \$392. The large farms made more than small ones; owners made larger farm incomes but smaller labor incomes than tenants.

Specialized onion growing in Iowa.—The Pleasant Valley onion district of Scott County, Iowa, is an example of successful crop specialization, in striking contrast with the typical Corn-Belt farming prevailing in that State. Approximately 500 acres are devoted exclusively to continuous onion growing, the average size of farm being about 10 acres. The Iowa station found in a survey of the district that it requires 220 hours of man labor and 62 hours of horse labor to produce, harvest, and market an acre of onions. About 50 per cent of the total man labor is required during August to harvest and market the crop. The total crop is approximately 200,000 bushels annually, and it is produced during nine open months, leaving the winter months unoccupied. Home-grown seed is almost exclusively used and the crop is marketed immediately after harvest. This is an example of a type of farming which provides a living probably equal to that of the Corn-Belt farm with only part-time employment. However, it is a highly specialized business requiring a special type of person with an inclination toward intensive farming to be successful. The opinion is expressed that onion growing will succeed best as a community enterprise, and that it is not likely to be followed on the average Corn-Belt farm because the nature of the work and the care needed for onion production differs widely from that of the Corn-Belt farms.

Size and organization of North Dakota farms.—Records obtained by the North Dakota station from 159 owner operators covering their farm business for the year ended March 1, 1923, showed the average size of farm operated to be 817 acres, ranging from 160 to 3,600 acres. The farms of most frequent occurrence were from 320 to 960 acres in extent. Approximately 34 per cent of the farm area was devoted to wheat. Land represented 81 per cent of the investment, its average value being approximately \$20 per acre. Livestock, including work horses, amounted to 8.6 per cent of the investment and machinery slightly over 5 per cent. The average farm income was \$1,692, ranging from \$1,112 on small farms to \$2,300 on large ones.

The best size of farm for the region appears to be about 800 acres, with approximately one-third of the acreage devoted to crops, one-half of the crop

area being devoted to wheat, about one-sixth to oats and barley, and from 7 to 10 per cent to corn. Flax may be substituted for wheat to a limited extent, and alfalfa, sweet clover, and millet are important minor crops. For farms of the most common size, about 10 milch cows and double this number of other cattle are considered to be advisable, and the better organized farms with about 275 acres in crops require 9 work horses.

Farming systems in Iowa.—Studies made by the Iowa station in Warren County showed that in 1921 crops occupied 59 per cent of the farm land and pasture 37 per cent. Of the land in crops, 45 per cent was in corn, about 30 per cent in small grain, and the remainder in hay. Hogs comprised the most important class of livestock. Less than 20 per cent of the gross income from these farms in 1921 came from crops. Practically 25 per cent was realized from this source, however, in 1915 and 1918. About one-third of the total income came from hogs in 1921. The three outstanding items of cash expenditure in 1921—taxes, purchased feed, and hired labor—constituted 17, 14, and 12 per cent, respectively, of the total chargeable expense. The most profitable cropping system for this area is thought to be one with as little pasture as the soil and surface conditions of the farm justify and as much corn as can be produced without reducing yields. Wheat is the most profitable small-grain crop. Most of the corn crop is utilized in feeding hogs, although there is some cattle feeding on the larger farms, and many of the farmers combine a limited amount of dairy production with the general cattle enterprise.

Farming in the black-land cotton belt of Texas.—A study by the Texas station of conditions on 500 farms typical of the black-land cotton-farming belt in Rockwall County showed that in 1922 90 per cent of the land in the farms studied was improved, and of this 93 per cent was devoted to crops, of which cotton made up 67 per cent. Of the investment in farm capital 94 per cent was in land and permanent improvements and 6 per cent in machinery and livestock. Of the 500 farms, 450 hired labor at an average expenditure of \$346.38 per farm. Loans for various purposes amounted to an average of \$1,111.34 per farm. Of the amount borrowed 71 per cent was used for buying land and the remainder for making a crop and for living expenses. The net income per acre was found to be closely correlated with a number of factors,

particularly the yield of lint cotton per acre.

Organization and management of West Virginia farms.—Approximately three-fourths of the farms of the State are general or diversified farms, according to the West Virginia station, and as a rule are too small for profitable general farming. About one-half of the tillable area of the farms is under crops. The tendency is to increase the size of farms. The net cash income, not deducting interest, was found to vary from \$147 on medium-sized general farms to \$2,106 on large livestock farms. "Labor incomes were fairly high on the large livestock farms only, the average being \$1,388 per farm. The next highest average labor income per farm, \$499, was on the truck farms. Four groups of farms made minus labor incomes; the average farmer of these groups received nothing for his own labor and less than 5 per cent interest on his investment. The family incomes, or money available for the family living and paying interest, did not exceed \$471 per farm on the general farms, and it was not less than \$754 per farm on any other type. The outstanding improvements needed on a very large majority of the farms studied, were a larger farm business and a better utilization of labor. * * * Farming in West Virginia has become essentially livestock production and will likely remain such." Improvement of pastures is therefore of paramount importance.

Irrigation farming.—In a study of irrigation farming in Gallatin Valley, the Montana station found that the average labor income was \$555 in 1913, \$1,501 in 1918, minus \$731 in 1919, minus \$2,098 in 1920, minus \$1,268 in 1921, and minus \$96 in 1922. In every year the labor incomes covered a wide range, both above and below the average, and the comparative profitability of individual farms from year to year was very inconsistent.

The results of a detailed survey of a typical small reclamation project in Elko County, Nev., made by the Nevada station in the spring of 1924 showed that of the 31 families living on the project all owned land and some operated additional land owned by the company. The average total acreage farmed was 173 acres. Potatoes and dairying are the chief sources of income. The annual receipts from crops averaged \$461 and from sales of livestock \$368 per farm. The receipts from livestock products, principally cream, amounted to \$703. The labor income averaged \$753 per farm. The value of home-grown foods used by the family was \$441,

and the cash paid out for groceries was \$311 per family.

Marketing potatoes.—From a study of private potato marketing agencies and farmers' cooperative organizations at country points in western and northern New York, the New York Cornell station concludes that the farmers' cooperative associations, single-station dealers, and many-station dealers supplement one another and that their competition encourages the best efforts for efficiency and economy. The lack of proper accounting is one of the weak features of the business.

Creameries and cooperative milk shipping stations in North Dakota.—In 1923 there were, according to the North Dakota station, 1,235 cream stations, 1,209 of which were operated by centralizer creameries and independent cream buyers and 26 by cooperative cream shipping associations in North Dakota. One-third of these have been very successful. The average value of equipment of the cooperative stations was \$452, and the average operating expense \$1,822 per year. The successful stations handled an average of 76,527 pounds of butterfat and had an average membership of 105.

Chicago milk market.—The Illinois station found a tendency to overproduction of milk in winter and a shortage in late summer and early fall in the dairy regions contributing to the Chicago market. Distribution in the city was studied with special reference to its equalization and better utilization of the available milk supply. In the winter of 1923 the average daily sale of milk in one of the wealthier sections of the city was 1.65 pints per family, in nine poorer sections it was 1.96 pints. The estimated daily per capita consumption of milk was 1.01 pounds. The demand for dairy products varied with the season, the day of the week, and the temperature. These variations are fairly definite and can therefore be predicted. There was a certain amount of surplus that must be carried at all times because of the variability of supply and demand, but this necessary surplus is a cost of the business and should not unduly influence prices. It is especially unfortunate that a large amount of surplus milk comes in the winter, when production costs are high.

Marketing apples in Massachusetts.—The Massachusetts station found that it cost \$1.15 per bushel to market the 1923 crop in certain typical apple-growing sections of the State. Sale to buyers was shown to be the least profitable method of sale. Sales on commission returned the highest average prices and

the highest average margins over cost of marketing. The importance of grading was emphasized in this study.

Labor required for threshing.—The Illinois station found that in central Illinois approximately 11 hours of man labor was required to thresh 100 bushels of oats and 20 hours to thresh 100 bushels of wheat. In Franklin County, approximately 18 and 25 hours, respectively, were required. It is held that under favorable weather conditions and with efficient management 100 bushels of oats can be threshed with 6 hours of man labor and 10½ hours of horse labor.

Use of tractors on Ohio farms.—From a 5-year survey study of tractors which were being used an average of 256 hours per year, the Ohio station estimated the tractors to have a total life of 1,794 hours, or, on the basis of the amount received for tractors disposed of, a working life of 1,703 hours. The average hourly cost of operating 2-plow tractors was estimated at 93 cents and of 3-plow tractors \$1.41. The use of tractors was found to have brought about a reduction of 1.3 work horses per farm in western Ohio and 1 work horse per farm in eastern Ohio. A reduction in the quantity of feed fed to each remaining work horse was also possible. In western Ohio there was an actual reduction in the combined cost of power and labor per crop acre following the purchase of tractors.

Farm mortgage loans in Texas.—Farm mortgage loans were found by the Texas station to run from 1 year in the case of the commercial banks to more than 30 years in that of Federal and joint-stock land banks. A relatively low percentage of the mortgage loans was used for the immediate purpose of buying land and improvements. From 6 to 9 per cent of the mortgage was used to pay off short-time indebtedness. Approximately 62 per cent of the mortgage loans of commercial banks was arranged to be paid off in one payment at the maturity of the loan, 46 per cent of those of insurance companies, 92 per cent of those of trust companies, and 38 per cent of farm mortgage companies.

Permanent occupancy of farms in Iowa.—In a detailed survey of 385 farm homes and farm families in Hudson, Orange, and Jesup consolidated school districts, the Iowa station found that in general about 75 per cent of the young people intended to remain on the farm, and from 55 per cent in Jesup to 94 per cent in Orange district of the tenants who did not own land indicated that they expected to become farm owners.

Insanity among farm women.—Replies to an inquiry sent by the Ohio station to superintendents of the State hospitals for the insane in Ohio tended to refute the popular opinion that farmers' wives, because of alleged monotony of their lives, are more subject to insanity than women in other vocations.

Rural population groups in Missouri.—In a study of rural population groups by the Missouri station in Boone County, which was chosen as typical of the greater part of rural Missouri, 59 primary population groups (neighborhoods) and 15 secondary groups (communities) were found. Primary group consciousness varied from high to low-minus, owing to local factors. "It was highest in those neighborhoods which were some distance from a community center and in those in which the opportunities for social contacts were greatest. The school was found to be the strongest factor in the maintenance of primary group consciousness. Intergroup consciousness was developed best through the consolidated high school, followed by the church, the lodge, and the store. Neighborhood boundaries were cut across in the efforts of the people to reach preferred points for such service as church, trade, school, lodge, and blacksmith shop. Thus a farm family has at a given time a number of separate and conflicting group loyalties." As a result the neighborhood is losing much of the force it once had. This is being transferred to the larger community, which usually includes a town or village. This larger rural grouping is new and now has less vitality and intensity of group consciousness than the neighborhood, although it appears to be on the gain, and will be of increasing importance in the development of rural affairs. "The status of a community depends upon physical, economic, and social factors which in a few cases are entirely beyond the power of the community to modify. The future of most community centers depends upon the ability to render superior service to the adjacent farm population. The negro primary groups are gradually becoming less intense in their social solidarity due to the competition of the larger community centers."

Family income and cost of living in a small factory town.—From a study of the income and cost of living made by the New York Cornell station during the year ended August 31, 1919, in the small factory town of Groton, N. Y., it appears that the average family income for the year was \$2,013.43. Of this amount the husbands contributed 75.5

per cent, the wives 13.8, the children 2.2, and other members of the family 0.5 per cent. The remaining 8 per cent consisted of receipts from farms, gardens, and livestock. The average cost of living for the year studied amounted to \$1,659.30 per family, or \$615.83 per adult male individual. The percentage of total cash income saved increased with the family income. The 92 families saved 13 per cent of the cash income received, the average per family amounting to \$246.18. It is shown by comparison that even with a 33 per cent increase in earnings for certain New York City families they could hardly hope to save as much as did these families in the small town.

Rural store credit.—In a study made by the New York Cornell station it was found that most of the rural stores carried a large number of book accounts, few running higher than \$100, together with a relatively small number of notes,

most of which were for \$50 or more. Implement stores, as a rule, carried a considerable number of notes. The greater portion of the notes taken by country merchants from their customers were discounted at the local bank, with the exception of the few cases in which notes on farm implements were carried by the manufacturer. The average net cost of credit for all feed stores, including paid and unpaid labor in keeping records, the cost of office supplies and collections, and the loss from bad accounts, was \$1,507 per store; that for general stores was \$549. The ratio of credit costs to total sales varied from 2.23 per cent for general stores to 3.85 per cent for farm-supply stores, the average for all being 2.83 per cent. The ratio of credit costs to credit sales is said to indicate that credit customers should pay an average of about 5 per cent more than cash customers.

INVESTIGATIONS ON TOBACCO, WITH SPECIAL REFERENCE TO QUALITY

BY HENRY M. STEECE, *Specialist in Agronomy*

The pioneer efforts in experimental work with crops were aimed toward increased acre production and means of cultivating greater areas. This attitude persisted until a comparatively late date. Recently there has been excess production of certain crops, and the large surpluses depress the prices received by the grower who can not market his crops profitably. Indeed, the increased yields over a certain point may not suffice to pay for the additional cost of production. With a decreased demand for the lower grades of the product, the better qualities or grades stand out. In recent years plant breeders and other agronomists have endeavored to produce a better product or one possessing an outstanding quality. Increase in the protein content of wheat, variation in the oil or protein content of corn and of oil in soy beans, better brewing quality in barley, increase of the sugar content of sugar beets, quality and length in cotton fiber, flax, and hemp, improved seed value of potatoes, and the various demands for quality in leaf, type, burn, etc., of tobacco have called for elaborate investigations.

Tobacco, a conspicuous crop cultivated for both quality and yield, has been grown in the United States for over three centuries. From about 1,500,000 to nearly 2,000,000 acres have been devoted to tobacco in recent years and have produced a total of from 1,250,000,000 to 1,500,000,000 pounds. This country leads the world in total production and also in the number and diversity of distinctive types produced. A high degree of specialization has accompanied the rather steady expansion in acreage and production of tobacco during and since colonial days. Tobacco production has become definitely localized in each region because of the particular combination of soil and climate producing a distinct type suited for certain uses and differing in important characteristics from other types. The effects of soil and climate are said to be so marked that two regions will rarely produce exactly the same type of leaf.

A characteristic feature of tobacco culture as indicated by Garner et al.

(96)¹ is that the acre returns to the grower commonly depend as much or even more on the leaf quality than on the yield, because of the wide range in prices for the different grades of leaf. The best returns are usually had from the highest yields of the finer grades of leaf rather than from maximum total yields. In such types as most cigar tobaccos and dark fire-cured and air-cured leaf, moderately high yields are usually associated with high quality. In other types, e. g., bright flue-cured, high quality of product so depends on the physical and chemical properties of the soil that high yields seldom accompany the best quality. In nearly all types of tobacco, rank coarse growth appears to be incompatible with high quality and with maximum returns per acre. Therefore, highly intensive methods involving enrichment of the soil are limited in their application to tobacco culture.

Investigations at the State experiment stations, often in cooperation with the United States Department of Agriculture, having for their objects either the improvement of the quality of tobacco or increasing the yield, are indicated in the following pages. Varietal trials, entomological studies, and minor cultural and fertilizer tests, while of undoubted value, have been omitted in the review. The work of the experiment stations on tobacco prior to 1900 was dealt with in considerable detail in an earlier contribution from this office (94).

CLIMATE

Climate, an important factor in the distribution of tobacco cultivation in the United States, has a significant effect on the quality of the leaf. Good yields of tobacco of the best quality are generally produced under seasonal conditions tending to promote rapid unbroken plant growth.

Examination of climatic data and production statistics suggested that the yield of tobacco in Massachusetts (41) did not gradually decrease during the period 1910-1919. Low yields since

¹ Numbers in italics in parentheses refer to "References," p. 92.

1914 were due primarily to adverse climatic conditions. In general, rainfall seems to be the major limiting factor of growth (and this necessarily includes soil moisture), together with temperature. Excessive rainfall is invariably followed by a reduction in yield independent of temperature. Subnormal rainfall, accompanied by temperatures excessively above normal, reduces the yield, but with subnormal temperatures it does not apparently reduce the yield to any extent unless the rainfall is very much below normal.

SOILS

Tobacco can be grown in nearly every State in the United States, but certain soil types appear to be required for better qualities and superior flavor in the manufactured products. The physical and chemical properties of the soil decidedly influence the development of the characteristics of the leaf making its commercial value. From exhaustive studies of the relation of the soils to tobacco production, made by the United States Department of Agriculture (91), it was pointed out nearly 25 years ago that the light, sandy soils were used in Connecticut for the wrapper-leaf tobacco for domestic cigars and in Virginia and North Carolina for the bright yellow tobacco. Wrapper leaf is grown in the Connecticut Valley on a stony loam soil. In Ohio a filler tobacco for domestic cigars is grown on a gravelly loam; in Tennessee another gravelly loam type produced an export type of tobacco. The sandy loams in Maryland produce a smoking tobacco, in Virginia a manufacturing tobacco, in Connecticut a cigar-wrapper leaf, and in Pennsylvania a cigar filler. A fine sandy loam produces a cigar wrapper in Connecticut, and in North Carolina a bright yellow tobacco. The types of loam, silt loam, clay loam, and clay also produce a number of types of tobacco, according to the character of the soil and the climatic conditions.

Studies of the soil of experimental tobacco plats in Lancaster County, Pa. (59), with a comparison of analyses of typical tobacco soils, including those of Russia, of Sumatra, Java, Cuba, Brazil, Massachusetts, Connecticut, and North Carolina, led to the conclusion that, "despite the general impression that the best tobacco is grown only upon soil rich in organic matter, provided a proper soil texture and plant food supply be otherwise secured—a proviso shown by repeated experience to be entirely possible—the tobacco crop is

practically independent of the presence of natural humus in the soil."

Tobacco soils were grouped by the Massachusetts station (41) as regards acidity or lime requirement. Soils requiring up to 3,000 pounds calcium oxide per acre do not produce good crops, as a rule, but are comparatively free from root rots; soils needing from 3,000 to 8,000 pounds calcium oxide are in good tobacco condition, but in this group pathogenic fungi, which may cause root rot during certain seasons, are abundant. Soils requiring over 8,000 pounds of calcium oxide are usually comparatively free from such fungi, even in unfavorable seasons, but may yield tobacco of slightly inferior quality. Although 2-ton applications of peat produced yield increase, it was deemed too expensive, and cover crops, especially timothy or rye, were recommended. Low-yielding soils responded favorably to organic matter and acid phosphate but did not show the lack of potash.

The pine lands have been considered to be the best tobacco lands in Maryland (37), and chestnut lands next, whereas oak and hickory lands were commonly regarded as poor tobacco soil. Varieties in Alabama (1) generally produced more cured tobacco on branch bottom land than on white sandy upland soil. The adaptability of the Willis and Huntsville, Tex. (71), soils to the growth of filler and wrapper tobacco has been reported on.

FERTILIZERS

Characteristic of tobacco is its rather large requirement for plant food for proper growth and the effect of the kinds of nutrients supplied on its quality. Besides the natural needs of the plant for plant foods, the finest qualities are grown on light sandy soils, which naturally have small amounts of plant nutrients and therefore must be heavily fertilized. The effect on quality of the leaf as well as the yield must be considered. The soil, seasonal conditions, the type grown, and local usages may affect the correct practices.

Extensive fertilizer experiments at the Connecticut State station (10, 13, 14) showed castor pomace to give more wrappers than cottonseed meal. Potassium-magnesium-sulphate led the potassium salts in production of wrappers and in total crop, whereas cotton hull ashes generally produced smaller crops than other potassium sources but made more wrappers. Linseed meal gave the greater wrapper yield, and the quality of the produce was better than

with cottonseed meal or castor pomace containing equivalent amounts of nitrogen. The quantity of wrappers increased regularly with the quantity of cottonseed meal or castor pomace applied. The yield of wrappers was greater when nitrogen was supplied only as castor pomace than when part was applied as sodium nitrate. The short wrappers differed somewhat in chemical composition from the long wrappers in further studies at this station (15). Differences in ether extract, fiber, and nitrogen-free extract contents were not traceable to the fertilizers used. Excessive nitrogen applications resulted in a much higher nitrate content and enhanced the protein and nicotine contents. The most potash was in tobacco receiving most fertilizer potash. In general the tobaccos having most lime had least magnesia, and vice versa. Comparatively large percentages of magnesia were found in tobacco receiving fertilizers containing much magnesia, which did not damage the quality of the leaf. The percentage of sulphuric acid in the leaf was very much larger when sulphates were used in the fertilizer, and the burn of tobacco receiving high-grade sulphate was very unsatisfactory. The ash of tobacco dressed with stable manure contained five times as much chlorine as the ash from any other lot in the series.

The plats of both shaded and unshaded tobacco receiving the largest quantity of lime at the Connecticut State station (18) showed a good deal of "white vein," the best unshaded tobacco being that receiving 1,000 pounds of lime per acre and of the shaded tobacco 2,000 pounds per acre. The results suggested that the use of lime may not, in all cases, have a deleterious effect on tobacco. Fertilizer experiments at the Connecticut tobacco substation (8) during 1922-1924 indicated that complete substitution of mineral for organic sources of nitrogen should be avoided and the quality of tobacco maintained. Mineral carriers may advantageously supply half of the nitrogen. Decided depression in yield and quality followed the use of excessive quantities of phosphoric acid. The use of potassium-magnesium-sulphate seemed without advantage where reasonably large quantities of organic fertilizer were applied. When the quantity of fertilizer was reduced the subsequent reduction in yield and quality more than offset the saving in fertilizer cost.

Investigations at the Georgia Coastal Plain station (22, 23), in cooperation with the United States Department of Agriculture, demonstrated the need

of acid phosphate on new land, potassium starvation and breakdown of the plant resulting from withholding potash from the fertilizer, the beneficial effect on growth and quality of tobacco extending beyond the plant food in stable manure, and a considerable net increase in the returns from heavy as compared with medium or light applications of fertilizer. Nitrogen from several sources appeared better than from a single source. Better color (24) resulted where 1,000 pounds of 8-3-5 fertilizer containing 10 per cent of phosphoric acid was used than from 1,000 pounds with less phosphoric acid. Commercial fertilizers increased the total yields of tobacco in Guam (25) but not the percentage of marketable leaf. The continued use of lead arsenate spray and fertilizers on the same plats resulted in the highest yield and quality of tobacco leaves.

Commercial fertilizers materially increased the yield and improved the quality of Burley tobacco in Kentucky work (27) reported as early as 1890. Increase was had whether potash, phosphoric acid, or nitrogen was used separately or in combinations. Potash and nitrogen in combination seemed necessary for best results. The best combinations appeared quite profitable. Potassium either in the form of chloride or sulphate gave similar effects. Nitrogen as sodium nitrate seemed to produce the best quality of leaf. Later fertilizer trials with Burley in Kentucky (34) indicated that tobacco may respond to commercial nitrogen only where neither manure is added nor crop residue returned. Experiments on Lexington field, Kentucky (30), and elsewhere indicated that under some conditions in the central bluegrass region it is profitable to fertilize tobacco heavily with mixtures containing high percentages of nitrogen and potash in addition to phosphate, particularly in the absence of a good grass or clover sod or sufficient manure.

Nitrogen appeared to be the limiting factor on the soils, inorganic forms giving better yields than organic forms, with the reverse true as to quality, in fertilizer tests in Maryland (39) in co-operation with the United States Department of Agriculture. Phosphates did not increase yields but stimulated growth and promoted the proper ripening of the crop, resulting in a lighter color in the cured leaf. Potash gave only small yield increases on "rested" land, whereas soil continuously cropped to tobacco showed a decided need for potash. Liming produced increased yields of tobacco only when nitrogen

was not liberally supplied in the fertilizer. The darker tobacco following liming is said to be due to excess nitrogen made available. In previous Maryland experiments (38) high-grade potassium sulphate produced the best tobacco, and potassium carbonate furnished by cottonseed hull ashes the next best. Potassium salts containing either much chlorine or magnesium produced a tobacco of poor quality which cured badly and burned very poorly. Potassium sulphate produced a better burning tobacco than any other of the potassium salts in yet earlier trials in Maryland (36) whereas potassium chloride always gave tobacco with a poor burn and a bad ash, as did lime and magnesium compounds in most cases. Phosphoric acid did not degrade the burning qualities. Complete commercial fertilizer and manure produced tobaccos similar in burning qualities, and in most cases better than where no fertilizer was used.

In early cooperative experiments in Massachusetts (40) cottonseed meal, linseed meal, and castor pomace, with enough sodium nitrate or potassium nitrate to furnish one-fourth of the nitrogen needed, proved equally good as nitrogen sources for tobacco. Sodium nitrate with acid phosphate or dissolved boneblack, surpassed potassium nitrate under similar conditions. Cottonseed hull ashes and high-grade potassium sulphate proved the best potassium sources. Potassium nitrate gave good results when used with an alkaline phosphate or with potassium-magnesium-carbonate. Although 2 tons of peat per acre produced increased yields at the Massachusetts station (41), this form of organic matter was deemed too expensive, and cover crops, timothy, or rye were indicated. Low-yielding soils responded favorably to additions of organic matter and acid phosphate but showed no lack of potash. Soils showing normal growth in the young tobacco plant soon after transplanting were found by the Massachusetts station (42) to contain comparatively small amounts of total solids, nitrogen, potash, and of most water-soluble constituents, whereas soils giving abnormal results showed an increase of over 70 per cent of total solids, over 85 of water-soluble nitrogen, and over 219 per cent of water-soluble potash. The combined effect of the total mineral constituents of the soil seemed responsible for the injurious effect rather than an accumulation of any one of the soluble elements. Drainage and crop rotation were suggested as measures of possible relief.

Barnyard manure gave the largest yield in early tests at the New York Cornell station (43) but was not more profitable than commercial fertilizers. Potassium sulphate gave somewhat better results than the chloride. On Miami gravelly loam in New York (46) tobacco yields in an unmanured 4-year rotation of corn, tobacco, wheat, and clover were not maintained by commercial fertilizers alone in cooperative experiments. Nitrogen seemed to be a limiting factor on the soil, whereas liming greatly increased tobacco production which responded less to phosphorus and potash. On Miami silt loam in a rotation of tobacco, wheat, and two years of alfalfa, tobacco production was maintained better, although the production level was considerably lower than on the gravelly loam.

Magnesia derived from either dolomitic limestone or double manure salts and kainit applied fairly liberally generally eliminated sand drown in experiments at Oxford, N. C. (54), by the North Carolina station cooperating with the United States Department of Agriculture. Calcium alone seemed to hasten the exhaustion of the magnesia supply of these soils. Cottonseed meal, sodium nitrate, dried blood, and ammonium sulphate ranked in order as sources of nitrogen. Acid phosphate excelled as a source of phosphorus. Potassium chloride produced more and better tobacco than high-grade potassium sulphate, although all tests have shown tobacco produced with the latter salt to result in a better burning quality. Potassium chloride also demonstrated its superiority over potassium sulphate at Reidsville, N. C. (52), in affording protection against wildfire, producing better and larger growth and giving immunity from sand drown. An increase in the nitrogen content of the fertilizer at Reidsville (51) was followed by greater susceptibility to leaf spot and other diseases, whereas potash appeared to stimulate disease resistance.

Elaborate fertilizer investigations have been carried on by the Pennsylvania station (58) in cooperation with the United States Department of Agriculture. Experiments in York County, Pa., indicated that the tendency of the soils to produce high-chlorine tobacco may be largely overcome by avoiding chlorine-containing fertilizers and manure. The yields obtained from commercial fertilizers also showed the entire practicability of growing tobacco on these, as well as other soils, without manure. An experiment in Clinton County showed that the use of commer-

cial fertilizers containing their potash in the form of sulphate or carbonate gives tobacco of more certain burning qualities than does stable manure. The yield and quality of tobacco grown with stable manure alone as a fertilizer were also greatly inferior. Finally, there were indications that the cause of the poor burn can not be put on the chlorine alone. Improvement in quality and burn as well as yield was shown by tobacco from plats at Ephrata where cottonseed meal, acid phosphate, and sulphate of potash were added to the manure. Large quantities of nitrogenous fertilizer did not pay on the productive soils in Lancaster County. In previous Pennsylvania (60) trials application of cottonseed meal, potassium sulphate, and dissolved boneblack gave a better yield of uniform and lighter colored leaf than did manure. Substituting linseed meal for cottonseed meal apparently improved tobacco flavor. Horn meal instead of cottonseed meal and the partial replacement of cottonseed meal by sodium nitrate reduced both yield and quality. Ammonium sulphate as a partial substitute for cottonseed meal slightly improved yield and wrapper qualities of the leaf, but flavor and aroma suffered a marked deterioration. Where potassium-magnesium-carbonate replaced potassium sulphate the leaf was more uniform and of better texture and burned slightly better without impairing the flavor or aroma. Using basic slag and omitting phosphate resulted in a low yield with a poor quality of leaf.

Little difference was observed between sodium nitrate and cottonseed meal as sources of nitrogen for tobacco on Highland Rim soils in Tennessee (69). Six tons of farmyard manure per acre with 800 pounds of a complete fertilizer proved more profitable than either alone. Tobacco was not directly benefited by liming. Sodium nitrate and ammonium sulphate produced the greatest increases in yield of dark tobacco at Clarksville, Tenn. (70), and were the most profitable in a comparison of nitrogenous fertilizers. Definite need for potash was not shown in cooperative trials in Montgomery County.

Nitrogen was most effective in the form of dried blood in early Virginia (72) tests, and the nitrogen of sodium nitrate was found more available than that of ammonium sulphate. Complete fertilizer surpassed any incomplete fertilizer with tobacco in Pittsylvania County, Va. (79), and acid phosphate led the single element carriers in acre value. Increases in yield and quality of leaf followed heavy applications of fertilizers.

Returns from tobacco were less on limed plats. Experiments with sun-cured tobacco in Virginia (80) indicated that a complete fertilizer containing a high per cent of phosphoric acid is essential to producing maximum yields of good quality tobacco, nitrogen being second in importance. However, potassium also seemed essential. For sun-cured tobacco satisfactory sources of nitrogen would be half from sodium nitrate and half from ground tankage. Lime was quite beneficial where ammonium sulphate was used and of slight value with sodium nitrate. The recent work has not shown potassium sulphate to be superior to potassium chloride for sun-cured tobacco. Since this tobacco is used largely for chewing, any adverse effect that potassium chloride would have on the burning quality is unimportant. The investigations suggest the application of from 1,000 to 2,000 pounds of 8-3-4 or 8-4-5 fertilizer to the acre for sandy soils unmanured, and about 1,000 pounds of 8-3-3 fertilizer on the heavier types of soil or where much manure is applied before the tobacco. Heavy applications of well-balanced fertilizers did not cause tobacco to fire or burn on the hill.

ROTATIONS AND COVER CROPS

The cropping systems followed in the producing districts differ to a considerable degree, according to the soil, local farming practices, and the type of leaf grown. Rotations were found profitable and maintained yields in Virginia (76, 78) with dark tobacco, a rotation suggested being based on tobacco, followed by wheat, grass, corn, and cowpeas. The land could be left in grass for one or two years. Work in the sun-cured tobacco district in Virginia (77) recommended a 7-year rotation: Tobacco, wheat, grass, corn with crimson clover as a cover crop, cowpeas, and red clover. Crop rotations were also found necessary and profitable in this district. Declining yields in Virginia sun-cured rotations (80) seemed due to black root, possibly caused by growing cowpeas directly before sun-cured tobacco. Liming and heavy applications of fertilizer in the rotation resulted in increased yields. Results obtained with bright tobacco in Pittsylvania County, Va. (79), indicated that the tobacco rotation on bright tobacco farms should not include legumes and the soil should not be limed.

Burley tobacco in a 4-year rotation of wheat, clover and orchard grass, orchard grass, and tobacco in Kentucky (34) gave a considerably better

quality of leaf and average yields than where tobacco followed corn and other crops. In 3-year rotations, tobacco after a redtop sod was decidedly superior to that grown after wheat or rape. Manure on grass sod did not seem to reduce the quality appreciably in Kentucky (32). Poor yields and quality of leaf were obtained where soy beans were included in the 3-year rotations, this crop seeming to encourage root rot. Tobacco showed striking superiority on freshly cleared hardwood land as compared with old land at Reidsville, N. C. (53), and continuous tobacco was much better than that alternating with corn. Continuous cropping with tobacco was found dangerous at Oxford, N. C., especially where tobacco wilt prevails.

Closely allied to rotations is the use of cover crops in conserving and adjusting soil fertility and condition. Tobacco growers concerned with diminishing yields were urged by the Connecticut State station (6) to test timothy as a cover crop at least three years in succession as the only visible alternative to temporarily replacing tobacco with other crops. Tobacco yields at the Massachusetts station (41a) on plats having had a timothy cover crop were consistently lower than those without cover, and while the quality was about the same, a higher proportion of longer leaves was found in the no-cover crop. In another experiment, for four consecutive years the timothy cover consistently failed to increase yield and to improve quality. It seems that the timothy cover crop should be used cautiously by the tobacco growers, especially where the presence of brown root rot is suspected. *Vicia villosa* appeared to be a valuable cover crop for tobacco in both Connecticut (4) and Wisconsin (82). The relatively large amounts of chlorine taken up by broom sedge and pine from lands in Maryland (37), rested in order to reclaim them for tobacco, was held to explain the improvement of such lands for tobacco. Crimson clover early fall seeded on tobacco stubble and turned under in May greatly increased yield and quality.

BREEDING

Nearly all of the experiment stations working with tobacco have endeavored to improve the crop by selection, hybridization, or introduction of new varieties. Some of the genetic work with tobacco has been reviewed by the writer (97) in a previous report.

Investigations at the Connecticut State station (21) showed that, although environment is of prime importance in any system of tobacco breeding, and quantitative characters and, especially quality of cured leaf, are largely dependent on this factor, heredity is also significant, and poor types will give unfavorable results, even under optimum environmental conditions. The only known means of producing variability as a source of new types is by crossing. The number of new forms which will appear, due to a particular cross, will depend on the number of germinal characters by which the parent plants differ. Breeding work by this station (5) in cooperation with the United States Department of Agriculture and Harvard University showed that, as a rule, characters such as leaf size, leaf shape, number of leaves, and type of leaf, are inherited independently. An external similarity of size characters in tobacco varieties does not necessarily mean a genetic similarity. There seemed good reason for believing that quantitative characters are inherited in the same manner as qualitative characters. Quality of cured leaf is a complex character and due to many conditions, environmental as well as inherited. An added difficulty is that the quality of leaf must conform to trade ideals.

Selection did not result in better quality or yields in Ohio (56), whereas in the later generations of certain hybrids better than the parental yields were obtained. Study of certain hybrid strains indicated the possibility of breeding for special adaptations, such as drought resistance and a greater ability to utilize profitably the less available forms of plant food.

A cross at the Wisconsin station (84) of two strains, said to be mutants from common Connecticut Havana, gave rise to a strain said to possess considerable commercial value, the chief advantages being the quite erect rather broad leaves of uniform size from top to bottom of the plant, one or two leaves more per plant, with greater average size and a greater yield than ordinary Havana. The quality is said to be equal to that of Connecticut Havana. Improved strains of cigar tobacco have been developed by hybridization and subsequent selection at the Pennsylvania station (58).

SPACING AND TOPPING

Besides weather, soil, and the general characteristics of the tobacco plant, the

number of leaves grown on a unit area affects the yield. In experiments in Pennsylvania (58) high topping at 15 to 18 leaves resulted in the highest gross yields, and closer planting was more advantageous than normal planting. With the closer spacings in Wisconsin (81) the yield increased, the size and thickness of the leaves diminished, and the percentage of fillers increased. Tests on the Granville, N. C. (51), farm indicated that closer planting of tobacco can increase yields without injuring the quality. Plants spaced 16 inches apart gave the highest acre yields of filler, wrapper, and trash in Ohio (55). The decrease in yield and in total value per acre resulting from wider plantings was continuous. The closest planted tobacco was rather flimsy, perhaps because of immaturity and delayed ripening. During 1906 and 1907 suckering produced gains ranging from 193 to 340 pounds per acre over not suckering. Topping plants in full bloom a few weeks before harvest improved the crop in Connecticut (3) and made it ripen more evenly on the stalk. Leaf cured on the stalk was lighter in color and more papery and less elastic than that picked or primed before curing.

HARVEST

In studies at the Wisconsin station (81) of the influence of time of harvesting tobacco upon the yield and thickness of the leaf, the tendency of the leaf to become thick as the time after topping increases was more manifest in the leaves from the earliest topped plants. The thickness and dry matter of the leaf as well as yield tended to increase up to 32 days after topping. Zimmer Spanish tobacco harvested about four weeks after topping in Ohio (55) generally gave a greater total weight and higher percentage of filler and wrapper than when harvested three weeks after topping. Two strains of the wrapper type harvested in Pennsylvania (62) by priming produced considerably more than when harvested and cured on the stalks. The gain by primed crops seemed due to greater average maturity and smaller decomposition and loss in the curing of the primed leaf. These field grown tobaccos were far inferior in wrapper quality to shade-grown Sumatra and Connecticut Havana leaf. Priming also resulted in gains in yield in North Carolina.

SHADING

The culture of high quality cigar wrapper leaf under an artificial shade of

cheesecloth or slats has been a comparatively recent development. The effect of shading on the leaf was observed in Connecticut (3) where about 9 pounds of unshaded Broadleaf were required to wrap 1,000 cigars, whereas only about 3 pounds of shaded Havana seed leaf and Broadleaf were needed. Shaded Broadleaf was not as elastic as open grown. Shaded plants grew slower than unshaded at the Connecticut State station (18) and showed the bud lower. After topping they produced unusually large thin leaves, were ready for cutting two weeks after unshaded plants, averaged less in weight, and their stalks were smaller and lighter.

Porto Rican (68) experiments indicated that shading increases the yield, quality, and percentage of wrappers enough to make the practice profitable, providing it is done only on soils suitable for growing wrappers and proper care is given the crop throughout growth and during curing and fermentation. A shelter tent experiment in Pennsylvania (61) proved that Sumatra leaf could be produced in Pennsylvania approaching the average imported Sumatra in color, luster, fineness of vein, wrapping capacity, and burn. A strain adapted to the Pennsylvania sandy loam and climatic conditions was developed. Shading tobacco with coconut leaves reduced yields at the Guam station (25), although more first-class leaves were obtained during the long, dry periods.

DISEASES

Although new tobacco areas have been opened up, the districts have been constant in location so that most soils are subject to continuous or repeated extensive culture. This naturally results in an accumulation of diseases and insects affecting tobacco in particular. Production of a good yield and high quality of leaf up to the manufacturing stage has been increasingly difficult in spite of the increased knowledge and experiences of the growers. Plant diseases, factors which cause average annual losses estimated to be about 5 per cent of the crop value or nearly \$25,000,000 annually in the United States, have been studied by all the stations in the tobacco growing States. Although the literature is voluminous, space limitations compel the citation of but a single publication, compiled cooperatively by the Wisconsin station and the United States Department of Agriculture (86). The information assembled summarizes data largely obtained by the experimental activities and studies of the Connecticut State, Florida, Ken-

tucky, Massachusetts, North Carolina, Ohio, South Carolina, Tennessee, Virginia, and Wisconsin stations, and of this department, describes important tobacco diseases, gives the causal organisms where known, and outlines control methods.

Among the important diseases causing loss of plants are damping off or bud rot, sore shin, stem rot, black shank, Granville wilt, and Fusarium wilt. Black root rot, brown root rot, root knot, and broom rape are also responsible for stunted growth and losses of plants. Wildfire and blackfire, bacterial diseases which render the leaf ragged and deformed with consequent low value for manufacture of quality goods, are traceable to plant bed infection and like certain other diseases may be controlled by proper sanitary measures. Wisconsin leaf spot and frog-eye are of less importance in this regard. The losses from mosaic are a consequence of the reduced yields due to dwarfing of the plants and the mottling or abnormality of the leaves which render them unsuitable for use for certain purposes of manufacture. Frenching, often confused with mosaic, has leaf deformities and chlorosis also characteristic of mosaic. Typical of frenching are the numerous "shoe stringy" leaves.

A blanching or chlorosis of lower leaves on very sandy soil during seasons of excessive rainfall, known as sand drown, has been shown due to a shortage of magnesium in the soil or fertilizer. Certain adverse results also follow the lack of potash, nitrogen, and phosphoric acid.

After harvest the leaves are yet threatened by several destructive agencies. The conditions of curing, fermentation, and storage of the several types of tobacco must be most conducive to proper color, body, texture, elasticity, grain, burn, and other factors, composing quality for the separate types, and abnormalities during these processes are as important as those of the growing plant. The most common forms of damage in tobacco following harvest are shed burn or pole rot, stem rot, wet butts, white veins, must, and molds.

CURING

After harvest the tobacco leaf must undergo the curing process which consists essentially of a more or less rapid desiccation and consequent death of the leaf tissue. Elaborate studies have been conducted by State stations and by this department (85, 92, 93, 95) on methods of curing and also on fermentation or sweating.

The early curing experiments at the Connecticut State station were concerned with water loss during curing (17), and the curing of Havana seed leaf tobacco by artificial heat (9), and analyses were made of tobacco stalks when cut and after curing (12). Curing studies at the Connecticut tobacco substation (7) gave indications that shade Cuban tobacco harvested slightly green will yield a higher percentage of top grades than tobacco picked very green or ripe to overripe. Aside from production of more desirable grades, the time during which tobacco can be picked and still yield very large quantities of top grades with control curing was at least three times as long as with barn curing.

Kentucky (33) experiments indicated that as high a grade of Burley leaf can be obtained by flue curing at a relatively low temperature as by air curing, thus eliminating completely the danger of house-burning. In experiments at the Kentucky station (28) where Burley tobacco was badly affected with house-burn, application of 10° of dry heat for an hour or more ended the trouble, and where heat was continually applied no house-burn developed. With the temperature from 100 to 120° F. tobacco cured with a greenish cast, but this was overcome somewhat by applying moisture at the same time.

The best results in Porto Rican (68) curing experiments were obtained in a large shed with a mean temperature of 77.7° F. and a relative humidity of 73.67 per cent. The slightly lower temperature and higher relative humidity in this shed apparently favored obtaining the best results. Leaf curing on wires cost more than the stalk cured at the North Carolina station (47) but the product was larger and of better quality, making the net receipts very much greater. The difference in chemical composition of like grades resulting from the two methods of curing was also reported on from this station (48).

A parallelism was apparent at the Pennsylvania station (64) between the humidity of the air in the curing shed and the catalase content of the Hirschman strain of Pennsylvania Broadleaf tobacco, but this response seemed to be governed largely by the fertilizer treatment and methods of curing used. The best cures in Wisconsin (83) experiments were usually obtained between 85 and 95° F., provided the humidity was kept high enough. If the temperature is too low or the humidity too low, the leaf usually cures out with a greenish color. When the temperature

is too high the leaf is killed quickly and develops an olive-green color. If, however, the humidity is too high, damage occurs owing partly to development of decay fungi in the tissues.

FERMENTATION

The details of extensive fermentation studies have been reported from the Connecticut State station (11, 17). The upper leaves, short seconds, and first wrappers differed considerably in the proportions of water, dry matter, nicotine, and other constituents lost by fermentation. Short wrappers (16) decreased slightly in weight after fermentation but more than doubled in average fire-holding capacity. In experiments in cooperation with the United States Department of Agriculture (90) in fermenting Connecticut tobacco, the bulk method seemed superior to the case method of fermentation usual in Connecticut, greatly shortening the period of fermentation, tending to give a better color and aroma, and largely eliminating the element of chance. The fermentation process was considered remarkably successful in studies of barn curing and bulk fermentation (20).

Although the evening and setting of colors by both methods were satisfactory, the elasticity and water-retaining capacity and the taste of the bulk-fermented tobacco was far superior to control-fermented lots at the Connecticut tobacco substation (7). Much residual green coloring matter was present in the control-fermented but almost none in bulk-fermented tobacco, which had much more brown coloring matter. Control fermentation in the cabinet seemed to affect more the surface and not the body of the leaf to any great degree. The protein was not reduced more than half as much in the control-fermented as in the bulk-fermented tobacco. The chemical changes in the resweating of seed-leaf tobacco at the Pennsylvania station (65) closely resembled those of the first sweating process, of which the resweat seemed to be a continuation. Most of the nicotine lost is evidently lost by volatilization.

COMPOSITION

Numerous analyses have been made on the tobacco plant, its component parts, the leaf in various stages of growth, during curing and fermentation and on the manufactured product. Analyses of the tobacco plant at different stages of growth were reported from the Virginia station (73). Comparing high-grade and low-grade bright flue-

cured grown in different Virginia (74) counties and in different years, the ash was about the same, and the lower grade contained about twice as much of each of nitrogen, phosphoric acid, potash, magnesia, and sulphuric acid as the high grade. The sodium and insoluble matter in the high grade was about six times as much as in the low grade, while the chlorine was about the same.

Results of extensive investigations in Ohio (57) showed that the composition of tobacco was modified more or less by different fertilizer treatments. Sodium nitrate application generally resulted in a decrease in total ash, phosphorus, sulphur, and chlorine, and increased the potassium content. Lime decreased the calcium and increased the magnesium in the tobacco complementarily. The most nitrogen was found in tobacco from unfertilized soil. Tobacco from plats receiving organic nitrogen has a higher nitrate nitrogen and nicotine content. Tobacco from plats treated with potassium contained more potassium than where none was applied, and tobacco from potassium sulphate or potassium nitrate plats contained more potassium than from potassium chloride plats. Tobacco from the manure-treated plat contained the most chlorine of any of the tobacco not fertilized with potassium chloride. Acid phosphate, used in combination with potassium chloride, tends to increase the chlorine content, and sodium nitrate to decrease it. Although potassium chloride used with acid phosphate and sodium nitrate excelled other potash forms in yield, this has been more than offset by the poor quality of the tobacco, as shown by smoking tests of cigars. Potassium in forms other than the chloride improved the quality of the tobacco. Sulphur present as sulphates in the tobacco exerted only slight influence on burning quality. Acid phosphate applied alone improved quality; in combination with potassium chloride any favorable effect appeared to be counteracted. Variations in flavor, aroma, and fire-holding capacity did not seem due entirely to the presence or absence of any one compound but are more or less dependent upon the total constituents of the tobacco.

Fertilizer results in Indiana (26) agreed in general with those reported above from the Ohio station. Plants variously fertilized with acid phosphate had a small petroleum ether extract and possessed the most agreeable aroma. Although the composition of tobacco may be greatly modified by fertilizer

treatment, the tobacco commanding the best price was grown on relatively poor sandy or clay soil, unsuited to corn, but producing a leaf characterized by a low percentage of extractives, proteins, and nicotine, and suitable for making a cigar of pleasing taste and aroma.

The good division of any grade usually contained a larger percentage of nicotine and generally more nitrogen and nitrate than the common in studies at the Kentucky station (31). Burley contained more nitrogen, nitrate nitrogen, phosphorus, potassium, and calcium than the dark tobacco and less nicotine, ash, silicon, and magnesium. The proportions of ash constituents, other than phosphorus and magnesium, differed considerably in the good and common grades. The good seemed to have the most potassium. Burley wrappers had the least silicon and calcium but the most potassium, the fillers the least ash and potassium, and the smokers the most ash, silicon, and calcium. Dark tobacco averages indicate that the leaf has the least ash and silicon but the most potassium and calcium, with the reverse holding in the trash.

NICOTINE

Considerable attention has been paid to the relation of the forms of nicotine and the organic acids of tobacco to the strength of tobacco intended for smoking purposes, with the aim of reducing the nicotine content or changing it by curing into forms more pleasing to smokers. The value of the nicotine for insecticide purposes has led to better extraction methods and also the breeding of tobaccos with higher nicotine contents.

According to observations at the North Carolina station (49) the nicotine at maturity is found mainly in the leaves, the percentage in the whole leaf in American grown tobaccos ranging from 1.96 to 5.53. Coarse rank growth is associated with a rather large nicotine content. The percentage of nicotine and albuminoids seemed to be materially increased by the extensive use of nitrogenous fertilizers. A large percentage of nitrogen in the form of albuminoids is usually accompanied by a high nicotine content. The percentage of nicotine in the leaf is largest just as the leaf reaches maturity, but the amount is materially reduced by the various fermentation processes before manufacture. Though nicotine is the active principle of tobacco and is desirable to a certain extent, the high-priced varieties examined contained relatively little.

The nitric nitrogen appeared to be chiefly confined to the stems, and was not present in the leaf in appreciable quantities, except when the soil contained large quantities of nitrogenous fertilizers. The difference in chemical composition of like grades resulting from curing by the stalk process and by the leaf process on wire in North Carolina (48) was chiefly due to the manner and time of harvesting, being most noticeable in fillers, where the increased growth caused by priming the lower leaves in the leaf-curing process resulted in larger percentages of albuminoids and nicotine. Analyses at different growth stages showed that the nitrates were confined almost entirely to the stalk and stems in the younger growth of the plant, whereas the other nitrogenous substances were more abundant in the leaves.

Investigations at the Kentucky station (31) showed that the good division of any grade usually contains a larger percentage of nicotine than the common. Of the Burley grades, the fillers usually contain the most nitrogen and nicotine and the smokers the least. In dark tobacco the leaf usually has the most nitrogen, nicotine, and nitrate, and the trash the least. The Burley tobacco of both 1920 and 1921 contained more nitrogen and nitrate nitrogen but less nicotine than the dark tobacco. The differences in nicotine content at this station (34), especially in waste and very inferior tobacco, were such that the average percentage was not deemed a safe basis for the proportions of tobacco and water used in a spraying infusion. An improved method for the determination of nicotine in tobacco and tobacco extracts was developed at the Kentucky station (35).

Comparison of the Burley, Pryor, and Oronoco varieties at the Virginia station (75) showed very little difference in nicotine content in the plant taken from the plant bed; at the time of topping the agreement was very close as to the leaf, whereas in the stalk Burley contained about two and three times as much as Pryor and Oronoco, respectively. The difference is very slight in the root. At time of cutting the nicotine contents of the leaf were similar in Pryor and Oronoco, but Burley had over 0.5 per cent less than Oronoco and over 1 per cent less than Pryor. The percentages in the stalk at this time were similar in the three varieties. Among different grades of manufacturing tobacco light tobacco contained the least and the dark the most nicotine, which ranged from 1.54 per cent in high-grade bright flue-cured to 5.56 in English shipping. In

the dry matter of 11 varieties of tobacco grown at the California station (2) the nicotine content varied from 2.23 per cent in Vuelta Abajo to 9.03 per cent in Pano de Sumatra.

The total nicotine content in a sample of Connecticut wrapper-leaf tobacco (89) was 3.39 per cent before fermentation and 2.89 per cent after, while the nicotine soluble in petroleum ether amounted to 1.6 and 1.01 percent, respectively. The undesirable sharpness or pungency of the smoke from certain types of cigar filler appeared to be due almost entirely to the volatile, easily soluble form of nicotine. On the other hand, the true physiological effects of the smoke seemed proportional to the total quantity of nicotine. The pungent, harsh quality of the smoke is partially removed by protracted resweating and aging of the tobacco, whereby the easily volatile nicotine is largely expelled.

NICOTIANA RUSTICA

The tobacco species known as *N. rustica* has been found to possess much more nicotine than the varieties of *N. tabacum* usually grown for manufacture into products for smoking and chewing. Analyses at Pennsylvania State College (67) of *N. rustica*, whose nicotine content had been increased by selection, disclosed that plants topped during growth contained 2.75 per cent of nicotine, suckered plants 3.79, plants topped and suckered 4.4, and untreated plants 1.61 per cent. In every case the percentage of nicotine in a topped or suckered plant greatly exceeded that of an untreated plant. Different kinds and quantities of nitrogen carriers seemed to affect profoundly the nicotine content of plants of *N. rustica* at the Pennsylvania station (64). Frosting appeared to increase the nicotine content and a further increase was noticeable after harvesting.

Considerable differences were observed at the New York State station (44) in the nicotine content of *N. rustica* from different sources and also among individual selections. The nicotine content was found higher in topped than in plants not topped. Broadcasted plantings were low in nicotine, whether highly fertilized with nitrogen or not. Dried blood and ammonium sulphate but not sodium nitrate seem to have increased nicotine to a small extent. Strains of the Pryor variety (*N. tabacum*) contained twice the amount of nicotine found in the previous year.

The investigations at this station (45) indicated that under identical conditions *N. rustica* develops a nicotine content about three times as large as do common strains of *N. tabacum*. Local environmental factors during growth seemed more potent than seed source in determining the nicotine content of a given variety of *N. tabacum*. Warm weather, favoring rapid growth and early maturity, evidently produced increased percentages of nicotine in the tobacco. The noticeable effect of soil treatments upon the nicotine content was slight compared with the seasonal or climatic influence.

BURNING QUALITY

Experiments on the burning quality of the leaf have been made by a number of the stations and by the United States Department of Agriculture. Tests with cigar tobacco by this department (87) indicated that for a good burn a heavy filler should be wrapped with a comparatively heavy wrapper and a light-bodied filler with a light-bodied wrapper, and that of the three components the filler exerts the strongest influence on the evenness of the burn. The wrapper and binder also strongly influence the character of the ash, and the binder very materially affects the ash of the wrapper. Other tests (88) were concerned with the relation of the composition of the leaf to the burning qualities of tobacco.

The fire-holding capacity of tobacco was increased by fermentation in Connecticut (14), although not equally in all cases. Tendency to "coal" when wrapped on a cigar was apparently not associated with deficiency in fire-holding capacity. Phosphoric acid seemed to influence combustibility only slightly in Maryland (37) but generally produced a marked yield increase. Potash salts seemed to be important factors in affecting the composition, forms containing considerable chlorine producing tobacco of poor quality and combustibility, whereas the sulphates and carbonates improved the quality and increased yield. In studies in North Carolina (49) burning quality depended more on the composition of the ash than upon the extent of fermentation. The best burning tobaccos were accompanied by a high percentage of ash constituents, particularly lime, and by potassium in proper combination. No connection was apparent between nicotine content and smoking quality in smoking tests of Ohio (56) filler tobacco.

GRAIN

"Grain," the small pimply projections found on the upper or outer surface of fully cured and sweated cigar tobacco of good quality, first appear a few days after curing has begun and the leaves have turned from yellow to brown. They are not found in fire-cured tobacco. They are composed of a mixture of salts, chiefly of lime and magnesia, with organic acids, largely citric and malic. Good burning Red Lion tobacco scored an average of 18 points for burn and 10.4 for grain at the Pennsylvania station (63), whereas poor burning tobacco scored 13 and 5, respectively, it appearing that grain development and burning quality are distinctly related. The good burning quality of leaf with well-developed grain is explained by assuming that the substances retarding the burn are gathered into the grain from surrounding tissue, which is left in condition to burn freely.

Grain was found not responsible for the marked hygroscopic properties of the tobacco in related studies by the United States Department of Agriculture (98). The small veins of the leaf showed the greatest hygroscopicity. In the tobacco studied the grain and burning properties were correlated. Other studies (66) related to those at the Pennsylvania station gave indications that the effect of salts in raising the temperature of the leaf may be significant, and that the action of caesium, potassium, and rubidium salts may be due to several complex factors. It seemed probable that these elements as carbonates, sulphates, and phosphates possess a specific catalytic action in combustion, and that the chlorides possess a negative catalytic action. The grain of wrapper was also investigated at the Connecticut State station (19).

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INVESTIGATIONS ON BACILLARY WHITE DIARRHEA INFECTION OF FOWLS

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Bacillary white diarrhea in the young chick is an acute, highly fatal, septicemic disease, manifested by a loss of appetite, sluggishness, drooping wings, and a pasty white discharge from the bowel, which adheres to the vent. It is caused by the *Bacterium pullorum* of Rettger (=*Salmonella pullorum*). The causative organism occurs in the ovary of the carrier hen, from which it passes into the yolk and is transmitted through the egg. Weakened by the organism, the chick may succumb within the shell or during the early days of its life. Should the affected chick survive, it is usually stunted and may remain infected through life, to transmit the disease through its eggs. The hen, the ovary of which is thus affected, may yet succumb to the chronic form of the disease.

IMPORTANCE—MORTALITY

Bacillary white diarrhea was, during the first quarter of the twentieth century, by far the most important disease with which the poultryman had to deal. In the light of present knowledge, gained through research work to a large extent conducted at the agricultural experiment stations in this country, it should soon lose this standing, since the application of the blood test has made it possible to eliminate the infection from and to maintain clean, or accredited, flocks.

Loss may be caused by the disease in the following ways: (1) A marked reduction in fertility, (2) lowered vitality or death of chicks in the shell, (3) death of the young chick, (4) stunting of chicks that survive, (5) reduction in the number of eggs laid, and (6) even death of adult fowls from chronic and acute forms of the disease.

In a flock of 17 chicks observed by Rettger (2)¹ in Indiana, in 1899, over 82 per cent succumbed to the disease. Of the chicks in a flock studied in 1900 (3), 87.5 per cent died, while the disease killed about 80 per cent on two adjoining farms. Graham (5), of the Ontario Agricultural College, reported in 1904, losses of fully 75 per cent of brooder chicks within 5 to 10 days after hatching. Reference to poultry journals of about that period shows an extensive correspondence on the subject,

losses of 50 to 75 per cent of entire hatches being not uncommon, and frequent appeals were made to the experiment stations to investigate the disease. Gifford (8) reported in 1905 that white diarrhea had cost him thousands of chicks in the preceding 14 years.

A mortality of practically 100 per cent was observed at the Connecticut Storrs station (13, 26) in 1906 in incubator-hatched chicks from eggs from different parts of the State. Graham (17), in Ontario, in 1908, reported a large loss of chicks between the fifth and tenth days, with a gradual dropping off up to 6 weeks of age. Some died quickly, others lingered for a week or more, and a few appeared to recover but remained small, unthrifty, and subject to roup and other infectious diseases. In an outbreak reported by Rettger and Harvey (18), then of Yale University, in 1908, almost 60 per cent of the 146 chicks exposed succumbed, the mortality being less than in the outbreaks observed in 1899 and 1900. Many farms that had never known the scourge before had suffered the loss of hundreds of chicks during the preceding two years.

That heavy mortality occurs among chicks before and also shortly after hatching was pointed out by Dryden (20), of the Oregon station, in 1908, and again by Pernot (21), of the same station, in 1908. In their first report from the Connecticut Storrs station, in 1909, Rettger and Stoneburn (26) concluded that the mortality depends upon the virulence and numbers of the organism, the mode and time of infection, and, doubtless, upon the vitality of the chicks. They described it as one of the worst things with which the commercial poultry raiser in New England must contend. Pearl, Surface, and Curtis (33), of the Maine station, stated in 1911 that, of all the diseases which the poultryman is called upon to fight, there is probably none so destructive, year after year, as white diarrhea, the loss varying in different years and places from 10 to 90 per cent. They estimated that 50 per cent of the chicks hatched throughout the country are lost from this form of white diarrhea. F. S. Jones (34), of the New York State Veterinary College, reported in 1911 that eggs artificially inoculated with *B. pullorum* did not give a high percentage of hatches. He recorded the loss by a

¹Numbers in italics in parentheses refer to "References," p. 125.

commercial poultryman in New York of 90 per cent in incubator chicks and even more in hen-hatched chicks.

In further investigations, by Rettger and Stoneburn (35), in 1911, 100 day-old chicks given 4 to 6 drops of a 24-hour bouillon culture of *B. pullorum* showed a mortality of 71 per cent by the twenty-fifth day, whereas in the control lots only 4 per cent succumbed. The infected chicks which survived made less satisfactory growth. For some time they appeared stunted and weak, but eventually underwent more or less complete development. Trap-nest records indicated that infected hens were comparatively poor layers, this being especially true of hens in their second and subsequent laying years, such hens apparently laying regularly only in the spring and summer.

Kaupp (74), of the North Carolina station, stated in 1917 that the loss to poultry raisers from this disease was greater than from any other cause, perhaps greater than from all other infectious diseases combined. Losses of as high as 90 per cent of the station's hatch were recorded. In 1922 Kaupp (98) reported a death rate among young chicks of 75 per cent or more, the greatest loss occurring during the first few days up to, in some cases, two or three weeks.

Lewis (90), of the New Jersey stations, referred to it in 1921 as undoubtedly the greatest scourge of the poultryman. Beaudette, Bushnell, and Payne (99), then of the Kansas station, in 1923, reported a marked reduction in hatchability, 40 per cent of the several thousand fertile eggs recorded failing to hatch. They found that the adult carrier produced a much larger percentage of infertile eggs than does the normal hen (105). Newsom (129), of the Colorado station, reported in 1924 that, with the growth of larger hatcheries and the selling of day-old chicks, the disease had become very serious in that State, the mortality in many instances amounting to from 90 to 95 per cent of all day-old chicks received by certain poultrymen and farmers within the first week after their arrival, and many people hesitating to buy baby chicks under any circumstances. Roberts and Card (155), of the Illinois station, pointed out in 1925 that the losses may run as high as 80 or 90 per cent of the chicks.

Canfield (148), of the Michigan station, expressed the opinion, in 1925, that this disease probably was the cause of greater losses and more discouragement to poultry raisers and hatcherymen than any other poultry

disease. He pointed out that by far the greatest loss caused by this disease is in the death of young chicks. Other losses occur through reduction in the hatchability of eggs, reduced egg production, and the increased susceptibility of infected hens to other diseases. In a comparative study of infected and noninfected birds in a flock, the egg production averaged 136, or 37.37 per cent, in infected and 166, or 45.46 per cent, in noninfected hens. The hatchability was 35.9 and 43.1 per cent, respectively, and the percentage of liveable chicks 22.4 and 94.2 per cent. The age and number of hens observed was not stated. The trap-nest record of infected hens, reported by Doyle (156), of the British Ministry of Agriculture, in 1925, led him to conclude that the egg-laying power of the majority of carriers is very seriously impaired as a direct result of the disease.

Effect of *B. pullorum* in mammals.—In 1915 Smith and TenBroeck (48), of Harvard University, suggested that the closely related *B. sanguinarium* may be the cause of the occasional reports of gastrointestinal disturbances of man following the eating of the meat of infected fowls.

In April, 1916, Rettger, Hull, and Sturges (58) reported feeding experiments with rabbits, kittens, guinea pigs, and white rats, *B. pullorum* being introduced through the mouth and digestive tract. It was found that eggs which harbored *B. pullorum* in the yolk in large numbers produced abnormal conditions when fed, not only in young chicks and adult fowls, but also in young rabbits, guinea pigs, and kittens. The toxicity for young rabbits was most pronounced, the infection usually resulting in the death of the animals. In kittens the most prominent symptoms were those of severe food poisoning with members of the paratyphoid group of bacteria. It was pointed out that the possibility of infected eggs causing serious disturbances in young children and in the sick and convalescent of all ages must, therefore, receive serious consideration. These authors stated that Gage, in a personal communication, had reported finding rabbits very susceptible to even very small doses of *B. pullorum* subcutaneously injected, and for this reason it was very difficult to immunize rabbits to the organism. In 1916, Rettger (60) pointed out that since a large proportion of market eggs are infected with *B. pullorum* and soft boiling, coddling, and frying on one side do not necessarily destroy the *B. pullorum*, infected eggs may be the cause of serious disturbances

in susceptible persons, and especially in infants. He concluded that, although well authenticated instances of egg poisoning of this kind are lacking, it is not safe to assume that no cases have occurred, since the etiology of infantile stomach and intestinal disturbances is lacking, and the same is true of gastrointestinal disturbances of later life. Since the ailments caused by infected eggs would not be felt presumably until several days after their ingestion, little or no suspicion would fall upon the eggs.

Doyle (156), in 1925, reported guinea pigs to be susceptible, and rabbits very susceptible, to subcutaneous and intraperitoneal inoculation. Two rabbits that were given 3 drops of a broth culture in the eye died on the sixth and eighth day, respectively. A sheep inoculated subcutaneously with dead culture, then intraveneously with living organisms, developed no symptoms.

GEOGRAPHICAL DISTRIBUTION

Bacillary white diarrhea infection appears to occur throughout this country and in Canada, Japan, and Europe, and probably wherever poultry raising is practiced to any considerable extent. Doyle (156) states that it probably has existed in Great Britain for a very long time. It was recorded from Ontario in 1904 or earlier, by Graham (5). A writer in Farm Poultry in 1905 (10) recorded it as having occurred 20 years before, and other correspondents recorded it as occurring in Montana in 1905 (7) and in Utah in 1906 (12). It was first investigated in Indiana by Rettger in 1899 (2), since which time it has been studied by the experiment stations of many States, particularly those of Connecticut, Massachusetts, Maine, Rhode Island, New York (New York State Veterinary College), New Jersey, Maryland, North Carolina, Michigan, Indiana, Kansas, Louisiana, and Colorado, and Ontario, Canada.

In 1909, Rettger and Stoneburn (26) reported that extended inquiry had revealed the fact that the disease was prevalent throughout the greater part of the eastern section of the United States and in Canada. It was reported from Maryland by Gage (37), of the University of Maryland, in 1911, and as generally distributed throughout Massachusetts by Gage and Paige (51) of the Massachusetts station, in 1915. The disease was shown by Stafseth and Mallmann (114) in 1924 to have become widely distributed over the lower peninsula of Michigan. A study of its occurrence in the United

States was reported upon by Mulsow (81), of the University of Chicago, in August, 1919. From a study of publications and replies to letters written to all the State experiment stations, it was found that *B. pullorum* infection occurred in 18 States, in 12 of which, namely, California, Connecticut, Delaware, Illinois, Indiana, Massachusetts, Missouri, New Hampshire, New York, Oregon, Pennsylvania, and Rhode Island, it was of frequent occurrence, and in six, including Iowa, Kansas, Nebraska, Texas, Wisconsin, and Louisiana, it was of rare occurrence. No epidemics had been observed in 13 States reporting, and no studies made in 12 others. The occurrence of the closely related *B. sanguinarium* was recorded as frequent in 3 States (Connecticut, Massachusetts, and Rhode Island) and rare in 7 (California, Delaware, Iowa, Missouri, Pennsylvania, Washington, and Wyoming).

SUSCEPTIBILITY OF CHICKS

The domestic fowl appears to be the only animal susceptible to natural infection (150). From experiments reported in 1911, Jones (34) concluded that chicks are most susceptible to infection during the first 24 hours of life, are less susceptible after they have reached the age of 48 hours, and seem to be immune after the fourth day. In an experiment, six of fourteen 1-day-old and two of four 2-day-old chicks placed in contaminated quarters contracted the disease and died, and *B. pullorum* was isolated from each. Pure cultures were also obtained from four of the remaining chicks. After an extended trip among poultrymen who raise winter chicks, Rettger and Stoneburn (35) reported, in 1911, that a large majority had agreed that the chicks which are hatched in late fall, winter, or early spring are comparatively free from the disease. They concluded that infection from chick to chick does not take place after they are 3 or 4 days old. In 1912, Rettger, Kirkpatrick, and Stoneburn (39) pointed out that chicks which are 3 days old but of low vitality may more easily fall prey to the disease than 1-day-old chicks which possess much greater constitutional vigor. As a rule, however, the younger the chick the greater its liability to infection. They reported experiments in which four lots of 36 chicks each were infected when 36, 60, 84, and 108 hours old, respectively, with 4 or 5 drops of a broth culture of *B. pullorum*. It was found that the first 48 hours after hatching is the period of greatest danger of infection,

there being comparatively little danger to chicks of strong vitality after that time. Where the vitality was low, however, infection took place as late as the fourth or even the fifth days. It was seldom observed after the chicks had attained the age of 4 or 5 weeks, and there were few deaths as a direct result of the disease after the chicks had attained such age.

Canfield (148), of the Michigan station, found in 1925 that by far the greatest losses occur among young chicks from 4 to 16 days old. Chicks from 1 to 10 days old are principally affected, but deaths may occur up to the fourth week, according to Doyle (156).

SUSCEPTIBILITY AND INFECTION OF THE ADULT FOWL

Chronic form.—In 1909, Rettger and Stoneburn (26), reported that upon killing to market a large part of the old breeding stock at the Connecticut Storrs station in order to introduce new noninfected breeding stock, a large proportion of the fowls showed a pathological condition, particularly of the ovary. In experiments reported by Jones (34), in 1911, 2 cubic centimeters of a bouillon culture of *B. pullorum* injected into the breast and also into the wing vein of adults produced marked depression, which lasted for several days, but no other bad effects were observed, and the same results were obtained when larger quantities were injected, nor was any effect produced when large quantities of the culture were fed to adults. The organism was, however, found in the ovary and in the egg in the oviduct of 1 of the hens inoculated. Definite evidence of natural infection was first obtained by Rettger and Stoneburn (35), who reported, in 1911, that in every instance where hens known to be infected were killed and examined, the ovaries were abnormal in physical appearance and contained *B. pullorum*. They found that no matter how badly infected the ovary might be a large number of the ova were apparently normal. Little or no change of shape was observed in the small pathological ova, but they were more or less discolored and frequently showed slight changes in texture. The larger ova, however, often presented striking variations in shape and texture. They were frequently decidedly angular, and varied in their consistency from soft and liquid to firm and cheesy. There were various degrees of discoloration. In some instances the change in color was but slight, but frequently it was quite marked.

At times some of the ova were found to be of peculiar bright yellow; again, they were quite dark, almost black, and occasionally more or less mottled. It was noted that the most virulent strain of the organism obtained up to that time was secured from an infected ovary. While found regularly in the abnormal ova, it appeared to be present in comparatively small numbers. In their examination of the ovaries of half-grown pullets, they found strong evidence in support of the theory that infected female chicks which survived the disease continued to carry the organism in their bodies, not in various organs, but locally in their ovaries, and became permanent carriers. It was at that time thought that, since noninfected hens kept in the same pen for months with infected hens did not become infected, the organism is not transmitted in that way.

Gage (37), at the Maryland station, reported in 1911 that he had found an inflammation and gangrene of the ovaries of a hen from which he isolated *B. pullorum*. Two hens and a pullet received for post-mortem examination were found to have suffered from ovarian infection. Thirty-two chicks given 2 drops of a bouillon culture of the organism by mouth and 30 others which were inoculated subcutaneously with a culture from 12 of the ova taken from the ovary of the pullet, all succumbed within 6 days.

Inoculation experiments with adults made by Jones (38), in 1912, indicated that intravenous injections of hens with pure cultures of *B. pullorum* may cause a local disease of the ovary. The eggs from these fowls failed to reveal the presence of the organism. Rettger, Kirkpatrick, and Stoneburn (39), reported, in 1912, that their later work had suggested the possibility that the infection might pass from adult to adult. In order to determine whether the infection is transmitted from hen to hen, 7 infected and 7 uninfected hens were kept together in an open-front house for 22 months. By testing the eggs it was found that 1 hen was infected in 8 months, a second in 16 months, and a third in 17 months. All 3 were killed and examined, and the organism isolated from diseased ovaries. A fourth hen, which had laid but few eggs, also proved to be infected with *B. pullorum*. In an experiment with mature stock, 48 early-hatched pullets were placed in pens in 6 houses in October, and a small amount of a broth culture of *B. pullorum* was sprinkled over the litter in three of the houses two or three times a week. Eight

of the 24 hens kept in these 3 litter-infected houses laid eggs which were found to be infected, 9 revealed infection of the ovary when they were killed, and a tenth was probably infected. None of the hens in the 3 check houses became infected.

Gage (44) reported, in 1914, that the lobulated and retention cysts, which varied greatly in size, were a striking pathological condition found in the ovaries. Rettger (45) considered it probable that the most active layers are the most susceptible to ovarian infection, since the physiological activity of the ovary is such as to lessen its vitality. Rettger, Hull, and Sturges (58) reported, in 1916, that they had obtained results much similar to those of Jones, but on a much smaller scale. Bouillon cultures of *B. pullorum* fed to fowls with the regular dry mash caused the death of 3 in a pen of 12 hens within a period of 1 to 2 weeks. *B. pullorum* was found in the organs of 2, but no marked or gross lesions were found. Other hens which appeared to be affected completely recovered in a relatively short time.

Doyle (156) reported, in 1925, that 1 of 4 fowls receiving 1 cubic centimeter of broth culture subcutaneously died on the fourteenth day, while the remaining 3 appeared unaffected. Tested 10 days after inoculation, the agglutination titer was 1 to 100, and at the end of 3 months all gave a negative reaction. Of 4 fowls which received 1 cubic centimeter of broth culture intravenously, 1 died on the third day, and 1 on the twentieth day. The 2 remaining reacted to the agglutination test for over 6 months. Of 4 fowls given 2 cubic centimeters of broth culture by mouth, 1 died on the eleventh day and the remaining 3 reacted to the agglutination test for 3 months. With two fowls infected by the injection of 1 cubic centimeter of broth culture into the oviduct, the agglutination titer on the tenth day was 1 to 50 and 1 to 25, respectively. One died from an intercurrent disease, and the other was killed 7 months later and the organism recovered from the ovary.

Acute form.—That *B. pullorum* may be the cause of an epidemic among grown fowls was first discovered by Jones (40), who reported in 1913 upon an outbreak in New York State. The owner of a poultry farm with about 700 hens had fed infertile incubator eggs to his hens, 50 of which died within 30 days. Pure cultures of *B. pullorum* were obtained from the pericardium, liver, spleen, and ovary. Jones described the disease as a true septicemia with a some-

what constant group of lesions, giving an account of the symptoms and post-mortem findings at some length. The lesions usually found were minute necrotic foci in the liver, spleen, and pancreas and large necrotic foci in the heart muscle. The presence of a fibrous exudate on the capsule of the liver and spleen and on the pericardium and heart was quite constant. He found that the ovaries of fowls harboring *B. pullorum* are not always pathological. In 75 per cent of the spreaders the ovary was cystic, but in the remaining 25 per cent it was apparently normal. In this outbreak the first symptom noted was a paleness of the comb and visible mucous membrane, the comb appearing shrunken, scaly, and gray in color. The fowls appeared listless, and as the disease advanced depression became marked, the head drawn down, and the wings sagging. The appetite was lessened and diarrhea usually present, the tail feathers usually being soiled with yellowish-white feces. The disease ran a variable course, sometimes terminating fatally in 24 hours, but usually running a regular course of 4 or 5 days and sometimes even longer. The period of incubation was found to vary from 16 days to 3 weeks.

In 1917, Hadley, Caldwell, Elkins, and Lambert (73), of the Rhode Island station, reported upon the study of an epidemic among adult fowls in a Rhode Island flock, in which a mortality of about 10 per cent resulted. The organism isolated resembled the fowl typhoid bacillus but was finally identified as *B. pullorum*. They also made reference to two other outbreaks, one of which ran in a course absolutely parallel and caused the death of 4,000 out of a flock of 4,500 birds. The authors tentatively concluded that, as a general principle, when *B. pullorum* types assume a pathogenic rôle in adult stock, they tend to approximate the characteristics of *B. sanguinarium*, especially in the absence of the ability to form gas in dextrose or other sugars.

Gwatkin (160), of the Ontario Veterinary College, reported in 1925 upon two outbreaks in adult fowls in Ontario. In the first outbreak, 15 of a flock of 93 birds died, and a number of others were affected but recovered. In the second outbreak about half the flock was lost. *B. pullorum* was recovered from the ovaries of 55 of 60 hens which had reacted to the agglutination test.

Susceptibility of grown males.—It was thought by Rettger and Stoneburn (35), in 1911, to be quite improbable that adult males become infected, and examinations made on several occasions of

the testes of half-grown and adult males had given negative results. In feeding experiments with pure culture of *B. pullorum*, reported by Jones (38), in 1912, 6 of 40 chicks survived, 3 of which were males. The 3 males were reared, and, upon being examined as adults, were found free from infection. In agglutination tests reported by Rettger, Kirkpatrick, and Jones (54), in 1915, 2.9 per cent of 786 males gave positive reactions. The testes of 2 of the 11 males autopsied harbored *B. pullorum* in pure culture in large numbers, and in 4 of the males pericarditis and infection of the heart sac with *B. pullorum* was observed. All of the 157 males tested during 1915-16 (63), the second year (96 for first time), gave negative results. Of a total of 1,037 males tested, 2.1 per cent were found infected (63, 77).

St. John-Brooks and Rhodes (106), of Lister Institute, London, in 1923, obtained a strain of *B. pullorum* from lesions in a cock which gave typical *B. pullorum* reactions with acid and gas formation in glucose and mannite and agglutinated in 1 to 6,400 with *B. pullorum* serum. Four out of 5 cockerels purchased by the Kansas station (132) from an eastern State reacted to the agglutination test, and reference is made to several others that reacted. Beaudette and Black (172), in their report of control work with the disease in New Jersey during the year 1924-25, recorded tests of 1,478 males, of which 55 reacted. They found that the infection in males is most often localized in the pericardial sac, occasionally elsewhere, and apparently but rarely in the testes.

ETIOLOGY—PATHOGENESIS

That a specific bacillus is the cause of the disease was first discovered by Rettger (2), then of the University of Indiana, in the course of studies made in Indiana in the summer of 1899. He succeeded in isolating the organism in that year from the liver, and in one case from the spleen of hen-hatched chicks affected with what was referred to as septicemia. Four chicks (2 to 4 weeks old) from unaffected broods that were inoculated subcutaneously with 0.5 to 1 cubic centimeter of a 24-hour bouillon culture developed the disease. Pure cultures of the bacillus were recovered from the liver of each of the 3 which succumbed, and in one instance from lungs and kidneys. It was also identified in the blood beneath the skin, and in two instances in the feces. In stained sections of the tissues, small slender bacilli were occasionally found, few in number and scattered through

the sections. In 1901 (3), Rettger reported upon an epidemic occurring on three adjoining farms in Indiana, in which the same organism was proved to be the cause. He observed the disease in chicks 1 to 4 weeks of age, but chicks over 4 or 5 weeks of age did not appear to be affected. The inoculation of two chicks gave results similar to those in 1899. A detailed description was given of the organism, including its cultural characteristics and its resistance to antiseptics, followed by an account of its pathogenesis.

In 1904, Graham (5), at the Ontario Agricultural College, recorded the loss of fully 75 per cent of brooder chicks in 5 to 10 days, and pointed out that the disease had always been associated with chicks that had not absorbed the yolk properly. He had thought it might be an infectious disease, but a study made of it by a bacteriologist had given negative results. Gifford (8), in 1905, claimed the disease to be caused in the majority of cases by imperfect assimilation of the yolk, and V. A. Moore, as reported by Rettger and Harvey (18) in 1908, expressed the same view and considered the failure of the chicks to absorb the yolk to be brought about by a bacterial infection. In 1906, Graham (13), of the Connecticut Storrs station, reported upon the first occurrence of the disease in the station flock, which he concluded might be caused by a lack of vitality in the parent stock, musty food, faulty brooders, chills, overheating, or improper ventilation. It was pointed out by Ingalls (14), of New York, in 1907, that what is now known as bacillary white diarrhea is incurable, and different from the bowel trouble due to faulty feeding, uneven temperature in the brooder, poor ventilation, and filth. In 1908, Morse (16) reported investigations which led to the conclusion that white diarrhea is due to *Coccidium tenellum*.

A Pennsylvania incubator company was reported by Rettger and Harvey (18), in 1908, to have concluded that the disease was caused by bacteria, though they failed to produce the disease from the blood or diseased organs of dead chicks. In 1908, Rettger and Harvey (18) reported having produced the disease in five chicks, from 5 days to 4 weeks of age, by subcutaneous inoculations made during an epidemic. Two guinea pigs and a rabbit which they inoculated failed to contract the disease, although lesions appeared at the site of the inoculations and in one of the guinea pigs softened and became necrotic, the same cheesy contents having been observed as in some of the

chick lesions. In feeding experiments a 10-day-old chick fed a bouillon culture of the organism succumbed in four days, and the organism was obtained from the blood of the liver. An 8-day-old chick given bouillon cultures of the organism in its drinking water on two successive days developed the disease in nine days and died on the nineteenth day after the first feeding, the organism being recovered from the liver and the heart blood. They observed that the serum of a chick injected with dead and living cultures agglutinated the organism, as did the serum of an immunized rabbit. Its general morphological and cultural characteristics led them to place the organism in the colon-typhoid-hog-cholera group. They pointed out the importance of determining whether the egg becomes infected before it is laid or afterwards during the incubation period, or whether the bacillus enters the chick after it is hatched. They were inclined to the belief that incomplete absorption of the yolk is in no way responsible for the disease, but that it is a result of it, as they frequently found the absorption was apparently complete.

Milks (19) reported, in 1908, upon a very fatal infectious disease of young chicks under 5 or 6 weeks of age, investigated at the Louisiana station. He isolated from the liver and heart blood and described what is considered by Rettger (24) to have been undoubtedly the same organism. Two chicks into which 0.25 cubic centimeter of a 24-hour bouillon culture of the organism was inoculated subcutaneously died in 6 and 21 days, respectively, and the organism was recovered from both. Two other chicks to which a 24-hour culture was administered in milk failed to contract the disease, and no evidence of disease was discovered at a post-mortem examination 6 weeks later. One of three mice inoculated subcutaneously with 0.25 cubic centimeter of a 24-hour bouillon culture died 20 days later with septicemic lesions, and the organism was recovered from the liver. The other two showed no effect except abscess formation at the point of inoculation.

Pernot (21), of the Oregon station, in reporting on chick mortality in 1908 stated that he had constantly found a pathogenic organism present in the unabsorbed yolk of all chicks that had failed to hatch or had died shortly after hatching, and was led to the conclusion that birds died in the shell from toxemia. The same organism was isolated from chicks affected by a whitish diarrhea. In 1909, Hadley (22), of the

Rhode Island station, reported investigations which had led to the conclusion that *Coccidium cuniculi* was the cause of the common form of white diarrhea in chicks. In a communication to Rettger (24), he reported having found *B. pullorum* in some of the chicks which had died.

In 1909, Rettger (24), in a paper that was read before the Society of American Bacteriologists in December, 1908, reported further, describing methods for the isolation and identification of the organism, and for the first time gave the name *Bacterium pullorum* to the causative organism. He also proposed the name "bacillary white diarrhea" to distinguish it from other forms of white diarrhea. It was found that the organism may be present in all of the internal organs of the chick, but particularly in the liver, spleen, lungs, and heart. The fact that the most careful search may reveal only a few scattered bacilli in one or two of the organs, while the remaining organs appear sterile, was pointed out. Even when the liver, spleen, heart, and lungs contained so few of the bacilli that the latter are found with some difficulty, they might easily be detected in the unabsorbed yolk. What was considered to be of importance also, was the frequent occurrence of the specific organism in the crop, stomach, and intestine. In a few cases *B. pullorum* was found practically pure and in large numbers, but as a rule the organism was mixed with other forms, especially *B. coli* and members of the *subtilis* group. Putrefaction rendered it difficult to find *B. pullorum*, as it was overrun by *B. coli* and other bacteria. It was very difficult to detect the bacilli in question in the dirt of the floors or grounds on which the chickens were running. Rettger also obtained additional evidence to show that chicks may acquire the disease through food and water that have been infected with the specific organism. It was suggested that chicks may be infected before they leave the shell, and that such infection may come originally from the hens which lay the eggs or during the period of incubation, the bacilli getting into the eggs through the walls of the shell. An examination was made of at least 60 eggs from various sources without finding *B. pullorum* in the yolks of any examined.

In December, 1909, Rettger and Stoneburn (26) reported finding the organism in (1) the ova in the ovary of hens, (2) the yolk of fresh eggs, (3) eggs incubated for varying lengths of time, and (4) yolk sacs of fully developed chicks still within the shell, which they

considered as conclusive evidence that the hen was the original source of infection of the chick. They pointed out that the disease may be transmitted through an infected food supply. Thirty-four, or 68 per cent, of 50 chicks which received a few drops of water suspension of *B. pullorum* as taken from the incubator, and also added to their drinking water and used to dampen their food, succumbed. Of 180 other chicks to which *B. pullorum* was administered in a similar way, about 13 per cent succumbed. Of 396 chicks infected with bouillon culture of *B. pullorum* when 24 hours old and also given it in drinking water and on food, about 24 per cent succumbed as against 17 per cent in control lots. Eleven strong chicks were injected subcutaneously with a pure culture of the organism, and 100 per cent mortality resulted. A continuation of the search for the organism in the shell resulted in its detection in large numbers in the yolk of 1 of 12 fresh eggs. The yolks of 8 of 86 eggs which had been incubated for different periods of time were found to contain *B. pullorum* in large numbers.

Higgins (28), a Canadian pathologist, in 1909 considered the term white diarrhea to have been used to designate a number of widely separated affections. The form with which he was familiar was thought to be due, not to an infective agent, but "to a defective anatomical development prior to the emergence of the chick from the shell." The affected chicks which he had examined contained a partially absorbed yolk sac.

Jones (34) reported in February, 1911, that in six chicks examined in New York in April, 1910, a large unabsorbed yolk was found in each, the blood vessels surrounding the yolk being congested. *B. pullorum* was cultivated from their heart, blood, liver, and unabsorbed yolk. It was shown to be pathogenic for young chicks when administered orally within the first 48 hours after hatching, and also to chicks 3 days old when injected subcutaneously, and to cause death in from 4 days to 3 weeks. Half-grown guinea pigs were found to be susceptible when injected subcutaneously, and to die in from 24 to 48 hours. The essential lesion was a large edematous area beneath the skin of the abdomen. The organisms were recovered in pure culture from all the internal organs. A rabbit weighing 1,660 grams, which was injected subcutaneously with 3 cubic centimeters of a 48-hour bouillon culture, died 7 days later. The most pronounced lesions were enlargement, softening, and congestion of the heart.

The organism was recovered in pure culture from all the internal organs of inoculated chicks, guinea pigs, and rabbits. It was found that *B. pullorum* might be present in the egg, not only in the yolk of the embryo but in the white surrounding it and also on the inside membrane of the shell. The experiment indicated that the number of infected eggs was not great, but 1 of 69 eggs from infected flocks showing the presence of *B. pullorum*. It was shown that it is the yolk that first becomes infected. Eggs containing the organism appeared to be less likely to hatch, and this was further substantiated the following year (38). The conclusion was reached that infection does not take place from *B. pullorum* on the outside of the shell. That chicks are most susceptible to infection during the first 24 hours of life, the chances of infection decreasing as the chick becomes older, was indicated.

In April, 1911, Rettger (36) reported having found *B. pullorum* present in the ovary of a pullet, less than 8 months old, that was one of the survivors of an infected flock, thus showing the laying hen to be a carrier. The same month Rettger and Stoneburn (35), in their second report, in which they dealt at length with the source of infection, recorded finding the ovary of a number of hens to contain *B. pullorum*. They reported experiments in which large numbers of chicks were infected with three strains of *B. pullorum* from infected ovaries, eggs, and chicks, the disease being produced at will. The organism was isolated regularly from the liver and unabsorbed yolks of chicks.

In June, 1911, Gage (37) reported upon investigations at the Maryland station, in which he found *B. pullorum* in large numbers in the diseased ovaries of a hen, and in each of 12 ova taken from a pullet with a diseased ovary. His studies fully substantiated the work of Rettger and Stoneburn, showing *B. pullorum* to be the cause of the disease and the hen to be the original source of infection, transmitting the organism from the ovary to the egg. He concluded that most of the white diarrhea of chicks in Maryland was due to *B. pullorum*.

In February, 1912, Jones (38) reported that 34 of 40 1-day-old chicks fed pure cultures of *B. pullorum* died of the disease. The 6 which survived (3 males and 3 females) with 6 purchased pullets from an infected flock were reared. When examined, 1 of the 3 reared females and 2 of the purchased pullets were found to have diseased ovaries, from which *B. pullorum* was isolated.

He reported upon an experiment which confirmed the finding of Rettger and Stoneburn that certain fowls overcoming the infection may become spreaders of the disease. He considered it clearly proved that *B. pullorum* may lodge in the ovary of the adult fowl. Since the disease in the young chick is a septicemia, and the organism is in the circulating blood, it is probably carried in this way and locates in the minute ovarian eggs, the egg yolk in the ova being a medium well suited to its development.

In a report published in December, Rettger, Kirkpatrick, and Stoneburn (39) dealt with further investigations of *B. pullorum*, the channels of infection, and means of prevention. In January, 1913, Jones (40) reported upon an outbreak of an acute disease in adult fowls due to *B. pullorum*. The same month (41) he first reported the successful application of the macroscopic agglutination test in detection of the organism in the adult fowl.

In April, 1914, Gage, Paige, and Hyland (44), of the Massachusetts station, confirmed the observation of Rettger, that the organism is more readily isolated from incubated eggs than from fresh eggs.

In a report published in June, 1914, Rettger, Kirkpatrick, and Jones (45) first showed that female chicks which are infected with *B. pullorum* when small, may in some instances retain a localized infection in the ovary, thus developing into permanent bacillus carriers and becoming a constant source of danger to young and old stock. They showed further that this carrier condition may be established in fully 25 per cent of an infected flock, thus connecting the cycle of infection. The same month Rettger (46) presented further data on ovarian infection and direct transmission to the offspring.

In 1915, Smith and TenBroeck (49) reported a comparative study of *B. pullorum* and *B. sanguinarium*, which led to the conclusion that the production of gas by *B. pullorum* and not by *B. sanguinarium* in dextrose and mannanite bouillon or in dextrose only and the production of acid by *B. sanguinarium* and not by *B. pullorum* in maltose differentiates the two organisms (see p. 107). In 1916, Rettger, Hull, and Sturges (58) reported feeding experiments with *B. pullorum* and the toxicity of infected eggs (see p. 96). Taylor (59) concluded from his studies that, although there is a close resemblance in the biological characters of *B. sanguinarium* and *B. pullorum*, they produce distinctly different diseases. A

study by Gage and Martin (61) of the pathological changes led them to conclude that the disease in small chicks is a septicemia, and that the minute necrotic foci in the liver, spleen, and pancreas are the most characteristic lesions.

In January, 1917, Rettger and Koser (65) reported a comparative study of *B. pullorum* and *B. sanguinarium*, their findings being similar to those of Smith and TenBroeck in 1915. In May, Goldberg (69) reported studies of the fermenting properties of *B. pullorum* and *B. sanguinarium*, his results indicating that they are distinct species, and corresponding with those of Smith and TenBroeck in 1915 and of Rettger and Koser in 1917. In July, Krumwiede and Kohn (72) reported on bacteriological studies of the *B. pullorum* group. In November, Hadley, Caldwell, Elkins, and Lambert (73) reported on a study of *B. pullorum* infection in adult fowls. In an outbreak among adult fowls, a strain of *B. pullorum* was found in eggs laid by some of the affected fowls, which, in some cases, failed to produce gas. Alpha and Beta types were designated. They emphasized the point that *B. pullorum* infections were not limited to young stock, they having observed three epidemics in adult stock. In the flock studied, the birds had been dying one or two at a time, many having suffered from diarrhea. Inoculation experiments with fowls and laboratory animals gave negative results. A post-mortem examination revealed a typical picture of fowl typhoid infection, but in cultural studies the causative organism was found to possess the fermentation characteristics of *B. pullorum*. In experimental inoculations made with fowls, pigeons, rabbits, and mice the culture was found to possess very slight virulence.

In 1918, Hadley, Elkins, and Caldwell (76), in reporting on the colon typhoid intermediates as causative agents of disease in birds, dealt with the paratyphoid bacteria.

In January, 1919, Rettger, Kirkpatrick, and Card (77) recorded finding a large percentage of the hens, into the cloaca and oviduct of which *B. pullorum* was injected, to react to the agglutination test. Of these 25 per cent became permanent reactors. In April, Brown (78), of the Minnesota station, reported upon the relation of incubation to the occurrence of bacillary white diarrhea (see p. 104). The same month Scherago and Benson (79) reported experiments on the intradermal test for *B. pullorum* (see p. 117). In August, Mulsow (81)

reported upon a comparative study of *B. pullorum* and *B. sanguinarium*, his results being similar to those obtained by other investigators (see p. 109).

In 1921, Spray and Doyle (84), of the Indiana station, reported upon a study of the paratyphoids freshly isolated from chickens. They found 20 strains from chicks with lesions of bacillary white diarrhea and 2 strains from diseased ovaries of hens to be identical with a type strain of *B. pullorum*. In 1922, Gage (93), concluded that there are two forms of *B. pullorum*, confirming the findings of Hadley and his associates (73.).

In February, 1923, Beaudette, Bushnell, and Payne (99), of the Kansas station, reported upon a study of an organism from unabsorbed yolk of chicks dead in the shell, which they could not distinguish from *B. pullorum* by the fermentation reaction except by the inconstant reaction of the latter on maltose and xylose. Investigations reported by them in October, of the same year (105), showed it to be *B. pullorum*, and that the fowls had infected ovaries. A decrease of from 11.52 to 33.4 per cent in the fertility of eggs was found in infected hens. In September, Hitchner (104) reported upon the macroscopic agglutination test as influenced by the fatty content of the blood serum (see p. 116). The organisms of the fowl typhoid group were studied by St. John-Brooks and Rhodes (106) in October. A bacteriological study of fowl typhoid and allied infections was reported by Edington (130) in 1924.

Mallmann (151), of the Michigan station, reported in October, 1925, upon studies of the cultural, physiological, and morphological characteristics, the agglutinability of 47 strains, and the keeping quality of antigen of *B. pullorum*. The resistance of chicks to the disease was reported upon by Roberts and Card (155), of the Illinois station, in December.

Doyle (156) also reported, in December that he had found 2.6 per cent of 341 eggs laid by 14 infected hens trap nested for 110 days to contain *B. pullorum*. It was found that only 4 of the 14 hens laid infected eggs, but their percentages were 3, 8, 14, and 18, respectively. Since the organism was recovered from the ovary of all the remaining hens, it was thought that the organism would eventually have been found in eggs laid by the other hens. The organism was never isolated from the egg white, which, however, has no inhibitory effect on *B. pullorum* growth. He concluded that the in-

fected eggs were laid at very irregular intervals, and that the percentage, at least in some cases, may be much higher than it is generally supposed to be. In infection experiments, 3 of 6 chicks inoculated through the eye died on the fifth, sixth, and seventh days, respectively, and the organism was recovered from their internal organs. One of 4 grown fowls which received 1 cubic centimeter of a broth culture subcutaneously succumbed, as did 2 of 4 that received 2 cubic centimeters by mouth, and 1 of 2 that received 1 cubic centimeter by injection into the oviduct. Doyle isolated *B. pullorum* from 37 of 42 carrier fowls examined, it being found in the ovary of 88 per cent, the spleen of 26 per cent, gall-bladder wall of 21 per cent, kidneys of 9 per cent, liver of 4.7 per cent, and bile of 2.3. While it was found but once in the bile, the bile had no inhibitory effect on its growth. He concluded that the blood, bone marrow, and lung are not affected in the adult.

Gwatkin (160) reported in 1925 upon an outbreak in grown fowls in Ontario.

RELATION OF ARTIFICIAL INCUBATION TO THE DISEASE

That bacillary white diarrhea infection is more commonly met with in incubator-hatched than in hen-hatched chicks was the opinion expressed by many poultrymen in their early correspondence in poultry journals. W. R. Graham, of Ontario, as reported by Rettger and Harvey in 1908 (18, p. 279), pointed out that the disease is common in incubator and not in hen-hatched chicks. At the same time Rettger and Harvey stated that most investigators claim that the chief trouble lies in artificial incubation, as it is usually incubator-hatched chickens that are affected. Dryden (20), of the Oregon station, reported, in 1908, that 16.6 per cent of the chicks were dead in the shell when incubated artificially, while only 2.8 per cent of the chicks were dead in the shell when incubated under the hen. The belief of many poultry keepers that artificial incubation is the direct cause of the disease led to investigations by Brown (78), of the Minnesota substation at Crookston. Starting in 1912 with 600 Barred Plymouth Rock eggs laid by a flock affected with the disease, one-half were hatched artificially and one-half with hens. Eggs from the surviving pullets of the succeeding generations were hatched each year in a similar manner. Of the total number of chicks that died in the first generation, 66

per cent were affected with white diarrhea, including 2.7 per cent of the hen-hatched and 23.75 per cent of the incubator-hatched. The losses each year from white diarrhea in the incubator-hatched lots, starting with 23.75 per cent the first year, showed no indication of diminishing, and during the sixth year they increased to 69.48 per cent. The hen-hatched lots produced no white diarrhea chicks after the second year (1913). The percentage of loss from white diarrhea up to the age of 21 days for the seasons of 1913 to 1917 from eggs incubator hatched from the second to the sixth generations of the hen-hatched line was 25 per cent in 1913, 4 per cent in 1914, and none afterwards. The study led Brown to conclude (1) that white diarrhea can be controlled by the reversion to natural incubation, (2) that it disappears after the second generation of natural hatching, and (3) that it is not necessary to discard infected breeding stock in order to control the disease. No further work supporting this finding has been reported.

ISOLATION AND CULTURE

The organism causing this disease was first cultivated in 1899 by Rettger (2) on agar and bouillon from inoculations of blood of the liver and spleen. It stains with the ordinary aniline dyes but is Gram negative and does not produce spores. Rettger described the organism as a nonliquefying, nonchromogenic, aerobic, and facultative anaerobic bacillus. It is a long slender bacillus with slightly rounded ends. On agar plates small white colonies made their appearance in 24 hours at incubator temperature. On slant agar pronounced growth occurred in 24 hours. In agar-stick culture rapid growth occurred along the whole line of inoculation. On gelatin plates small white colonies made their appearance in 48 hours, and the gelatin was not liquefied. In gelatin-stick culture pronounced growth occurred in 48 hours along the whole line of inoculation. In bouillon abundant growth occurred in 24 hours at incubator temperature, and a similar growth took place in glycerin bouillon. On potato development was very slow. Milk was not coagulated, nor indol, phenol, or cresol produced. In studies made during an outbreak reported upon in 1901 (3), the development on artificial media, and particularly on potato was more rapid than that of the first culture, due, it was thought, to the greater virulence and vigor of the organism.

In 1908 Milks (19) made cultures from the liver and heart blood of chicks and obtained what was undoubtedly *B. pullorum* from six and *B. coli* from four. Its growth on various culture media was described. He also found it to be aerobic and facultative anaerobic, to grow best at 37° C. and feebly at room temperature.

The Bacillus No. 9, isolated in 1908 by Pernot (21) from unabsorbed yolk and heart's blood of chicks that failed to hatch or that died in a few days after hatching, was probably this organism (*B. pullorum*).

The organism was cultivated by Rettger and Harvey (18) in 1908 and its characteristics again described. They pointed out that its morphological and cultural characteristics place it in the colon-typhoid-hog-cholera group. It closely resembles the *Bacillus cholerae-suis* in its ability to produce gas in dextrose and mannite media although *B. cholerae-suis* is actively motile and causes a strongly alkaline reaction in milk, whereas *B. pullorum* is nonmotile, or practically so, and never turns litmus milk blue. Its cultural characters were also described by Rettger (24) in February, 1909, and by Rettger and Stoneburn (26) in December, 1909.

In July, 1909, Rettger (24) first suggested that the infection of chicks may occur before they leave the shell, coming from the hens that laid the eggs, or entering the shell through the walls during the period of incubation. In the first examinations, however, he failed to detect its presence. In December, 1909, Rettger and Stoneburn (26) reported examinations of the shells of 12 fresh eggs from infected fowls, which gave negative results. The yolk in one case contained the bacterium pure and in large numbers. The yolks of 8 of 86 eggs (from 11 different varieties of fowls) which had been incubated for different periods of time were found to contain *B. pullorum* in large numbers and apparently pure. In an examination of the diseased ovaries of 20 hens, pure cultures of *B. pullorum* were obtained from 9. The finding of this organism in (1) the ova in the ovaries of the hens, (2) the yolk of fresh eggs, (3) eggs incubated for varying lengths of time, and (4) yolk sacs of fully developed chicks still within the shell was taken to be conclusive evidence that the hen is the original source of infection of the chick.

Jones (34) reported in 1911 that the organism may be present in the eggs, having been detected in 1 of 69 eggs examined. Gage (37), in June, 1911, reported that in investigations at the

Maryland station he had used the slant agar inoculation from tissues method of Rettger with success in cultivating the organism. In April, Rettger and Stoneburn (35) described an improved method devised for detecting the presence of *B. pullorum* in the eggs, by use of which a large amount of the egg is utilized. By the employment of this method the presence of *B. pullorum* in fresh eggs was readily determined. It was pointed out, however, that a large number of eggs must be examined before the investigator is justified in drawing the conclusion that the hens are free from infection. They found that in infected eggs, if kept at 103° F., the regular temperature of a commercial incubator, *B. pullorum* multiplies rapidly and is readily detected in a few days, even in small amounts of yolk.

The improved method of Rettger and Stoneburn was employed in 1912 by Jones (38), who found that some of the eggs laid by 2 of 9 hens known to be carriers of *B. pullorum* contained the organism. Of 34 eggs laid by 1 of these 2 hens, 14.8 per cent contained *B. pullorum*, as did 8.9 per cent of 41 eggs laid by the other hen. *B. pullorum* was found to be present in the whites as well as the yolks of eggs rejected during incubation. Rettger, Kirkpatrick, and Stoneburn (39) reported in December, 1912, that with chicks which had reached the age of 4 or 5 weeks *B. pullorum* had so far disappeared from the blood that it was usually impossible to find it there. Jones (41) pointed out, in 1913, that *B. pullorum* was easily recovered from the cystic ovary. In fowls that agglutinate but fail to reveal any marked pathological changes in the ovary, he recommended the ovary be removed with aseptic precautions to a sterile Petri dish, and there cut into several small pieces, and then crushed with a sterile spatula and dropped into tubes of sterile bouillon. The tubes should then be allowed to incubate 24 hours at 37.5° C., and from this suspension pure cultures may be obtained either by the plate method or by the inoculation of slant agar tubes.

MORPHOLOGY AND STAINING

The organism was described by Rettger (2), in 1900, as a bacillus with slightly rounded ends, which grown on agar, is 1 to 2 microns long, 0.3 to 0.5 micron broad, and usually occurs singly. When grown in bouillon the size was found to vary considerably, being larger and longer, and often attaining a length of 3 or 4 microns, or growing out into chains of 2 or 3 bacilli. It

does not produce spores. First described by Rettger in 1900 as actively motile, this finding was later corrected, and the organism was described in 1908 (18) as nonmotile. It was found to stain with the ordinary basic aniline dyes, fuchsin and soap solution of methylene blue being the most satisfactory. It proved to be Gram negative and not to retain its color when treated with very dilute nitric, hydrochloric, or acetic acid. Sections to be stained required 15 to 20 minutes staining in fuchsin or soap methylene blue and rapid dehydration. The maximum temperature for the bacillus was 56 to 57° C. (132 to 135° F.) for an exposure of 15 minutes, and the optimum temperatures 35 to 37° C. (95 to 99° F.).

In 1908 Milks (19), of the Louisiana station, described the organism as a small aerobic and facultative anaerobic rod with rounded end, 1.3 to 1.8 by 0.5 to 0.7 microns, nonmotile, but with Brownian movement, Gram negative, and nonspore forming. He found it usually to stain uniformly with the common dyes, though a polar stain was seen in some cases.

The organism isolated by Rettger (2, 3) in Indiana in 1899 and 1900 was again obtained by Rettger and Harvey (18) in an outbreak in Connecticut in 1907, and its morphology and staining properties were again described by them, and also by Rettger and Stoneburn (26) in 1909. Jones (34), in 1911, described the organism as rod-shaped varying in size from 2 to 3.5 microns in length, with an average width of 0.5 micron. No capsules or spores were observed, and the bacilli were usually grouped singly or in pairs.

In a study of the morphological characteristics of 47 strains of *B. pullorum*, Mallmann (151), at the Michigan station, found no marked differences that would justify a separation of strains.

CLASSIFICATION—DIFFERENTIATION

The causative organism of this affection has been shown to belong to the intermediate, enteritidis or paratyphoid subgroup of the colon-typhoid group of bacteria, members of which subgroup are characterized by their ability to produce acid from rhamnose (72). Among other more important members of the subgroup are *B. enteritidis*, *B. cholerae-suis* (*suipestifer*), and *B. paratyphosus*. In the manual prepared by a committee of the Society of American Bacteriologists in 1923 (110), *B. pullorum* is placed in the genus *Salmonella*, species of which form gas from dextrose, and should be known as

S. pullora. The committee placed *B. sanguinarium* in the genus Eberthella, members of which do not form gas from dextrose, and accordingly it should be known as *E. sanguinaria*. *B. pullorum* is differentiated within the genus Salmonella, in that it forms acid and gas in mannitol, in dulcitol, and in levulose, but not in inositol or in maltose. *B. sanguinarium* is separated from other members of the genus Eberthella in that it forms acid in mannitol, in xylose, and in dulcitol, but not in lactose nor dextrin, and does not form indol.

B. sanguinarium (=*B. gallinarum* Klein, 1889), which is very closely related to *B. pullorum* and from which it must be differentiated, was first isolated in the United States by Smith (48), in 1894, during an epidemic among fowls in Rhode Island. It was first named and described by Moore (1) in 1895 from diseased fowls in the District of Columbia, Virginia, and Maryland, and the affection termed infectious leukemia. It was studied by Curtice (4) and Smith (4, 48) during an outbreak in Rhode Island in 1901, and the affection named fowl typhoid, by which name the disease is now commonly known. This close relationship has resulted in comparative investigations being conducted by a number of workers, particular attention being given to sugar fermentation tests because of the material difference in the action of the organisms on some sugar media. Such investigations were reported by Smith and TenBroeck in 1915 (49), Taylor in 1916 (59), Rettger and Koser in 1917 (65), Goldberg in 1917 (69), Krumwiede and Kohn in 1917 (72), Hadley in 1917 (73) and 1918 (75), Mulsow in 1919 (81), Spray and Doyle in 1921 (84), Gage in 1922 (93), St. John-Brooks and Rhodes in 1923 (106), Truche in 1923 (101), Edington in 1924 (130), Doyle in 1925 (156), and Mallmann in 1925 (151), who have found differences sufficient to regard the organisms as separate types.

Both organisms are Gram negative, and, as determined by the more accurate modern methods, neither form indol, although in the original account *B. sanguinarium* was recorded by Moore (1) as producing a small amount of indol.

Rettger and Harvey (18) reported in 1908 that *B. pullorum* produces both acid and gas in dextrose (20 per cent) and mannite (20 per cent) media. The gas consisted of carbon dioxide and hydrogen in the ratio of 1 to 3. In a further report issued in July of the following year, Rettger (24) stated that

he had found different strains of *B. pullorum* to vary in their gas-producing power in dextrose bouillon. Some of the organisms isolated failed entirely to produce gas in dextrose medium. Two particular strains, however, fermented dextrose and produced 5 and 25 per cent gas, respectively. The more active of the two strains lost this property within seven or eight months and was for a while strictly anaerobic, but the fermenting power was gradually being restored. Mannite was also fermented by some strains, but not by others. In 1909, Rettger and Stoneburn (26) and, again in 1914, Rettger, Kirkpatrick, and Jones (45) stated that some strains do not produce gas in any of the sugar media.

In 1911, Jones (34) recorded both the production and nonproduction of gas by *B. pullorum* on glucose and mannite bouillon. In a comparative study reported by Smith and TenBroeck (49), in 1915, it was found that recently isolated strains of *B. pullorum* produced a little gas in both dextrose and mannite bouillon or in dextrose only, but none was produced by the strain of *B. sanguinarium* used. A second difference was found in the action on maltose, which was acidified by *B. sanguinarium* and not by *B. pullorum*. In other respects the two appeared to be alike. The toxin production was found to be identical. It was concluded that the gas production of *B. pullorum* is of a fluctuating character, which seems to disappear during artificial cultivation. Smith and TenBroeck thought it possible that strains of *B. sanguinarium* when freshly isolated might produce gas. This latter point was apparently determined by Taylor (59), of the University of California, who conducted studies of an outbreak of fowl typhoid in that State in 1913, in which a freshly isolated strain of *B. sanguinarium* produced acid but no gas in dextrose in 72 hours. This was found by Goldberg (69) to be the same with year-old cultures. Agglutination tests made by Smith and TenBroeck (49) were found sufficiently definite to group the *B. sanguinarium* and *B. pullorum* types together. The close relation of the two was further shown by absorption tests.

In January, 1917, Rettger and Koser (65), reporting upon a comparative study of the two organisms, called attention to their close relation serologically. They found *B. pullorum* to produce gas (20 per cent) in dextrose and mannite media, while *B. sanguinarium*, whether recently isolated or artificially cultivated for many years, did not produce gas in any of the carbo-

hydrate media. A prolonged cultivation of *B. pullorum* did not cause it to lose its power to produce gas in dextrose and mannite broth. Dextrin, maltose, and dulcite were found to be attacked by *B. sanguinarium* with the production of acid but no gas, while *B. pullorum* produced no visible change in the media containing these agents except slight alkali production. The methyl red test applied to cultures grown in 1 per cent maltose bouillon was found to furnish a practical method of distinguishing between the two organisms, *B. sanguinarium* being methyl red positive and *B. pullorum* negative. Their findings were quite similar to those of Smith and TenBroeck in 1915.

In investigations reported in 1917, Goldberg (69) found four typical strains of *B. pullorum* to produce gas in various carbohydrates, including dextrose, mannite, galactose levulose, arabinose, and mannose, while *B. sanguinarium* lacked this power. His findings were similar to those of Smith and TenBroeck in 1915 and Rettger and Koser in 1917. In dulcite the four strains of *B. pullorum* produced slight acidity and gradually turned alkaline on prolonged incubation, while *B. sanguinarium* produced marked acidity. In dextrin results similar to those in dulcite were obtained, except that the acidity was not so marked. An atypical strain of *B. pullorum* was found which failed to produce gas in any of the carbohydrates, thus resembling the original Rettger strain. It was so markedly different from the other strain that Goldberg was in doubt as to whether it should be considered a strain of *B. pullorum*.

Krumwiede and Kohn (72) reported in 1917, that they had found gas formation by *B. pullorum* in glucose to separate it from *B. sanguinarium*. They found *B. sanguinarium* to form acid on maltose and dulcite, while *B. pullorum* did not. A culture, received from Smith and TenBroeck, of the strain of *B. pullorum* in which gas production was suppressed resumed its ability to produce gas from glucose, showing the tendency to variation in this characteristic.

Hadley (73), in 1917, reported that certain cultures isolated from infected eggs and also cultures isolated from adult fowls that died with a generalized infection failed to produce gas in dextrose broth. He pointed out that the *B. pullorum*-like strains that have the power to produce active and generalized infections in adult stock are differentiated from the strict type of *B. pullorum* as characterized by Rettger

(2), in that (1) they do not form gas in any carbohydrate media, and (2) they manifest a low ability to ferment maltose, dextrin, and dulcite. This led him to suggest the recognition of a duality of type: (A) *B. pullorum* A, possessing the chief characteristics described by Rettger, a gas-forming type whose immune serum agglutinates *B. typhosus* about equally with its homologous antigen, pathogenic for young chickens only, and (B) *B. pullorum* B, resembling the type A in its chief characteristics but differing in that (1) it does not form gas in any carbohydrate, (2) its serum (like the antifowl typhoid serum) does not agglutinate, in high dilutions, human typhoid antigens, and (3) it is able to produce natural generalized infections in adult fowls, but only to a slight degree, if at all, in young stock. Hadley found that aerogenic strains, even after years of cultivation in artificial media, never lost their aerogenic powers, and no anaerogenic strain ever became aerogenic. Edington (130, 156), on the other hand, stated in 1924 that every anaerogenic strain which he had studied in Great Britain became aerogenic on subculture. Hadley found that *B. pullorum* A manifests in maltose, dextrin, and dulcite an almost immediate lessening of the initial acidity; it is strictly maltose-dextrin-dulcite negative. *B. pullorum* B manifests a slightly delayed lessening of initial acidity, sometimes after a very slight increase (0.1 to 0.3 per cent); also a terminal alkalinity of a lower degree than in the case of the Alpha strains. *B. sanguinarium* gives an immediate increase of acidity, sometimes followed after some weeks by an alkalinity of low grade.

Studies reported by Hadley (76), in 1918, led to the recognition of six main disease types among the typhoid-like and cholera-like diseases of birds, which included (1) fowl cholera, due to *B. avisepticus*, of the Pasteurella group, (2) fowl typhoid, due to *B. sanguinarium*, of the actual paratyphoid group, (3) paracolon infections, due to paracolon bacteria in the strict sense, (4) bacterial white diarrhea, due to *B. pullorum* A, (5) infections in adult stock with *B. pullorum* B, and (6) infection with intermediate strains whose position is not wholly clear. *B. sanguinarium* is differentiated from the *B. pullorum* type in its ability to ferment maltose, dextrin, and dulcite; also from *B. pullorum* A by its failure to produce gas in any carbohydrate. *B. pullorum* is differentiated from *B. paratyphosus* B in being maltose-dextrin-dulcite negative. In respect to its reaction in litmus milk the *pullorum*

type is allied to paratyphoid A rather than to B. The *B. pullorum* A differs from *B. pullorum* B in that the latter shows a slightly greater tendency to form acid in several sugars and is anaerogenic.

Mulsow (81) reported, in 1919, an extensive comparative study of typical strains of *B. pullorum*, from which he was led to conclude that it can be distinguished from *B. sanguinarium* through its production of gas by most strains in several of the carbohydrates. Dulcrite and maltose were, however, fermented by *B. sanguinarium* and not by *B. pullorum*, although a few strains of *B. pullorum* attacked maltose slightly. The strains of *B. sanguinarium* studied ferment rhamnose slowly, while the strains of *B. pullorum* ferment it promptly. He pointed out that *B. sanguinarium* does not, in general, take the ordinary stains as readily as *B. pullorum*, and often when stained with fuchsin the central portion is only faintly stained. His strains of *B. pullorum* did not grow, as a rule, as luxuriantly on agar and gelatine media as did *B. sanguinarium* or other members of the group. All but one strain of *B. pullorum* and two strains of *B. sanguinarium* produced a blackening of the medium along the lines of inoculation in 24 hours, due to hydrogen sulphide production. In agglutination tests with serum of rabbits immunized toward several strains of *B. pullorum* and *B. sanguinarium*, no agglutination difference was observed.

Spray and Doyle (84), of the Indiana station, reported in 1921 a study of 21 strains of paratyphoids from 21 outbreaks of highly destructive disease among chicks and 2 strains from the ovaries of mature hens, all but 1 of which strains were typical *B. pullorum*. All the strains produced gas from one or more sugars, with the exception of 1 strain isolated from a chick, which fermented the proper sugars but did not produce gas from any. No correlation could be shown in gas production from various sugars; some strains produced gas from glucose and not from mannite, while the behavior of others was exactly the reverse. Repeated tests were necessary to demonstrate gas production by some strains. All of the strains and the control strain of *B. pullorum*, usually regarded as unable to ferment maltose, produced acid and gas in 1 per cent maltose serum water. Maltose infusion broth was not fermented. The method employed by Spray and Doyle in their fermentation study was largely based on titration, at varying periods, of extract or infu-

sion broth cultures containing 1 per cent of the desired carbohydrate. They found that the use of 1 per cent sugar serum water plus the Andrade indicator possesses certain advantages over titration, in that immediate and frequent observations may be made, gas production is readily detected, the slightest initial acidity may be noted, and reducing ability may be distinguished by the decolorization of the coagulated serum.

Investigations of 112 strains of *B. pullorum* were reported by Gage (93) in 1922. He found that *B. pullorum* was maltose-dextrin-dulcrite negative and aerogenic, while all cultures of *B. sanguinarium* studied were also maltose-dextrin-dulcrite negative but anaerogenic. These characteristics he found to be constant. It was found that whenever doubt arose as to cultural and morphological differentiations, the biochemical tests aided in making a final decision. From the examination of 600 avian specimens for the anaerogenic, nonmotile, maltose-dextrin-dulcrite positive form, which produced large spleens, associated with marked leukemic conditions, the true *B. sanguinarium* was identified only six times. Chick examinations conducted during the same period, representing several hundred examinations, all yielded typical *B. pullorum* cultures, with the exception of one culture which was probably an atypical *B. pullorum* form that has become anaerogenic. Several times the anaerogenic form was isolated from dead hens, indicating the correctness of Hadley's contention (73), that *B. pullorum* may assume a dual rôle. The cultures from eggs were always found to be aerogenic. The differential characteristics of the cultures isolated from dead chicks which had been hatched from eggs laid by positive reacting hens proved to be typical *B. pullorum*. The several hundred agglutination tests made demonstrated an interagglutinability of *B. pullorum* with *B. sanguinarium*, *B. typhosus*, *B. paratyphosus* A, and *B. paratyphosus* B antigens.

In February, 1923, Beaudette, Bushnell, and Payne (99) reported upon the investigation of an organism isolated from the unabsorbed yolk of chicks dead in the shell. This strain differed from the typical *B. pullorum* in that it produced some acid on maltose, as was found by Mulsow in 1919. Injected into the eggs on the sixth day of incubation it proved pathogenic for the developing embryos. Truche (100), of the Pasteur Institute at Paris, reported in April that he had found *B. pullorum* always to produce gas in mannite,

arabinose, levulose, and glucose, and considered this characteristic the most important in differentiating it from *B. sanguinarium*.

In 1923, St. John-Brooks and Rhodes (106) reported fermentation tests and serological differentiation work with material acquired by the Lister Institute, London, from various sources during the preceding three years. They found *B. sanguinarium* to be indistinguishable from *B. pullorum* on serological grounds, but readily differentiated by its production of acidity in dulcite and maltose. They report that the distinction between *B. pullorum* A and *B. pullorum* B appears to be very artificial, both strains having been shown to affect either adult or young stock. The 36 strains isolated at Lister Institute from cases of white diarrhea were all nonlactose fermenters and produced acidity in glucose and mannite, but failed to ferment dulcite. Of these, 18 gave acid and gas in glucose in 24 hours, 6 more gave gas in 2 to 5 days, and 2 more on subculture from glucose peptone water cultures. The remaining 10 strains proved to be anaerogenic. All the 36 strains gave complete agglutination with a *B. pullorum* serum (titer 1 in 3,200) prepared from a *B. sanguinarium* strain at a dilution of 1 to 100. Most of their strains were obtained from lesions in chicks, but some were from adult fowls. The strain from *B. pullorum* lesions in a cock gave typical *B. pullorum* reactions with acid and gas formation in glucose and mannite, and agglutinated up to 1 to 6,400 with *B. pullorum* serum. Most of the strains which did not produce gas in glucose peptone water were derived from young chicks under three weeks old. The strain of *B. pullorum* B which they received from Rhode Island produced acid and gas in glucose and mannite when tested, although doubtless anaerogenic at the time of isolation. Thus they were led to conclude that the distinction between *B. pullorum* A and *B. pullorum* B, at least in so far as their relation to infectivity of stock is concerned, is of very doubtful value. They found that *B. sanguinarium* not only produced the lesions of fowl typhoid in adult birds, but also caused lesions in young chicks indistinguishable from those observed in *B. pullorum* infections, while *B. pullorum* produced in adult stock the symptoms of fowl typhoid. The lesions of bacillary white diarrhea were, moreover, consistent with those of a general septicemia with localized congestion and necrosis, the increased excretion of uric acid which gives the name "white diarrhea" to the disease being a common

manifestation of generalized disorders in poultry. From these considerations it would appear that the two organisms are very closely related and may indeed be but varieties of the same species.

In 1924, Edington (130) reported that he had found agglutination and complement fixation tests to be of no value in the differentiation of *B. pullorum* and *B. sanguinarium*. Every anaerogenic strain of *B. pullorum* that he studied became aerogenic on subculture. Both types of *B. pullorum* were isolated by Konno (175) in Japan during the course of outbreaks in 1924.

In fermentation studies with 18 different carbohydrates, reported by Mallmann (151) from the Michigan station in 1925, only 2 of 47 strains of *B. pullorum* failed to produce gas in any of the sugars. These 2 he considered to be the anaerogenic strains described by Hadley as *B. pullorum* B. Only 3 of the strains produced gas consistently in all the fermentable sugars. The acid production in dextrose, mannite, galactose, levulose, mannose, and rhamnose broth was observed to be quite constant in occurrence, but on the other carbohydrates it was extremely variable. Biochemical tests showed variation in hydrogen sulphide and nitrites in Dunham's solution and nitrites in nitrate-peptone solution. These variations occurred among the strains and in the same strains at different times. No ammonia was produced by any of the strains in nitrate-peptone solution. In the first determinations with litmus milk all of the strains acted normally, but in the second and third series a number of them produced alkali after 14 days' incubation. The production of alkali was not constant for any 1 strain.

Doyle (155) reported, in 1925, tests of over 100 strains of *B. pullorum* isolated in Great Britain, the results being read on the tenth day. With maltose, lactose, saccharose, inulin, sorbite, and dextrin the results were negative, while glucose, mannite, and levulose tests gave acid and gas, or acid only. Strains isolated from chicks might be aerogenic or anaerogenic, the majority were aerogenic. He concluded that strains isolated from adult birds or from eggs may be aerogenic or anaerogenic, that the great majority are anaerogenic. The passage through young chicks of anaerogenic strains isolated from adults frequently results in the recovered organism having acquired the power to produce gas. An aerogenic strain which had been passed through an adult fowl was, on recovery from the ovary five months later, found to be anaerogenic.

There was no difference in the virulence of aerogenic and anaerogenic strains for chicks, adult fowls, rabbits, or guinea pigs. He concludes that the gas producing powers of *B. pullorum* are of a fluctuating character, and that there does not appear to be any reasonable grounds for making two groups, as has been suggested by Hadley (76). A comparative test was made of the gas production of 24 strains of *B. pullorum* in peptone water media and beef extract media with glucose as the test substance. In the peptone water 13 strains were aerogenic and 11 anaerogenic. Four strains were constantly negative for gas, 2 of which were isolated from chicks and 2 from adult birds.

It is pointed out by Doyle that the majority of workers now appear to agree that aerogenic and anaerogenic strains of *B. pullorum* can be isolated from both chicks and adults, and that some strains lose the power of producing gas while others acquire it after cultivation on artificial media.

TENACITY OF THE ORGANISM

In his initial study of the organism, Rettger (2) found that when exposures were made in bouillon at incubator temperature the organism was killed in two hours by (1) 1 to 60,000 solution of corrosive sublimate, (2) 1 to 220 solution of carbolic acid, and (3) 2.5 per cent carbolic acid plus 1.5 per cent soft soap, 1 to 6. In 1908 Milks (19) found bouillon cultures to be resistant to boiling for 15 minutes. A 1 per cent carbolic acid prevented growth after 17 minutes but not after 15 minutes, and a 2 per cent solution prevented growth after 2½ minutes. The effect was tested by adding 5 drops of a 24-hour bouillon culture to 5 cubic centimeters of the disinfectant, the mixture shaken, and subcultures made in bouillon at intervals of 2½ to 17 minutes, being incubated at 37° C. for 5 days.

In 1908, Rettger and Harvey (18) showed that *B. pullorum* was killed by formalin, 1 to 700, when exposed in a bouillon culture for two hours at 37° C. A culture of the organism injected into chicks six months after it had been obtained from infected broods was found to have retained to a large extent its original virulence. In 1909, Rettger (24) reported finding that the organism is readily injured or destroyed by very small quantities of mineral acids and of lactic acid. It was found to be extremely sensitive to very small amounts of the lactic acid, bouillon tubes being rendered sterile when the acid was present for two hours in the ratio of 1 to

400, or 0.25 per cent. The resistance of *B. coli* was fully twice as great as that of the chick organism, it requiring 0.5 per cent lactic acid to kill all of the colon bacilli during the two hours' exposure.

Jones (34) showed, in 1911, that the organism is easily killed by disinfectants, being destroyed by 1 to 1,000 corrosive sublimate and by 5 per cent carbolic acid in 30 seconds, and by 1 per cent carbolic acid, 1 per cent creolin, and 3.33 per cent lactic acid, respectively, in 5 minutes. It was killed by boiling in 1 minute, but was not destroyed by heating to 60° C. for 30 minutes. In an experiment reported by Jones (38) in 1912, in which 40 1-day-old chicks were placed in a brooder that had housed infected chicks, no infection resulted, indicating that *B. pullorum* will not remain alive in a brooder over winter.

In 1916, Rettger, Hull, and Sturges (58) reported investigations of the survival of *B. pullorum* in the yolks of eggs after various methods of treatment with heat. Poaching the eggs for one-half to four minutes rendered them sterile. Scrambled artificially infected eggs were likewise found to contain no viable organisms. On the other hand, fried and coddled eggs gave varied results. Soft boiling, coddling, and frying on one side only do not necessarily render the yolks free from viable bacteria. In egg yolk boiling for four minutes did not in every instance kill the organism. This is thought to be due to the peculiar protection afforded first by the shell, then the egg white, and finally by the yolk itself.

ANATOMICAL CHANGES

Macroscopic — Chicks. — Post-mortem findings were first reported upon by Rettger (2) in 1900. He found diseased chicks to be very much emaciated, the crop empty, the intestines pale and almost empty, the liver pale with the exception of a few patches and streaks which were of a dark red color, and the spleen, lungs, and kidneys apparently normal. Morse (16) reported in February, 1908, that he had found only about one-half of the affected chicks examined to have unabsorbed yolks. In March, 1908, Graham (17) described post-mortem findings based on examination of 463 chicks. He found the lungs in about 50 per cent of the affected chicks to show white spots, particularly next the ribs, these spots being generally quite hard and cheesy. Some lungs (those in which chicks got chilled) were observed to have no white spots, but

to be red, sometimes fleshy in color. Some yolks were of a gelatinous nature or almost like the white of the eggs, others hard and cheesy and very yellow in color, and still others like curdled custard, with an offensive odor. The ceca were frequently filled with a cheesy substance. Of the 463 chicks examined, 44.7 per cent had cheesy spots in their lungs, 29.8 per cent had hardened yolks, and 28.4 per cent abnormal ceca. There were 22 per cent with abnormal lungs, yolk, and ceca, and 35.4 per cent with both lungs and yolk diseased. In August of that year Milks (19) reported that the post-mortem appearances were not marked, but as a rule quite uniform. The digestive tract was normal; the liver constantly enlarged, dark in color, and engorged in blood; the gall bladder usually filled with dark bile and the ureters with white or yellowish waters; lungs normal in all cases; and the heart filled with blood, its external blood vessels usually congested. In an epidemic reported by Rettger and Harvey (18), in May, 1908, the post-mortem appearances were essentially the same as in the epidemics observed in 1899 and 1900.

In a paper presented at a meeting of the Society of American Bacteriologists in December, 1908, Rettger (24) pointed out that the ceca may be practically empty or be partly filled with a semisolid or rather firm cheesy matter, and that the crop is empty or filled with either a slimy liquid or with food. In every case where the specific organism was obtained from the internal organs of the chick, there was found also more or less unabsorbed yolk, while in chicks of the same ages which died from other causes and in the control chicks the yolks were usually found to be completely absorbed. The yolk sacs of chicks affected with bacillary white diarrhea (septicemic) varied in size from a small pea to an Italian chestnut. Rettger and Stoneburn (26), in their first report of investigations at the Connecticut Storrs station, in 1909, gave a detailed description of post-mortem appearances. They stated that, unless the chick had been dead for some time, the yolk was usually not found to be putrid, but merely stale. The lungs were described as apparently normal.

In 1911, Jones (34) reported the unabsorbed yolk to be the most characteristic lesion of the disease. Its size was found to vary from being fully undigested down to the size of a pin-head. Its consistence was found to vary with the course of the disease, it

being large and watery in the early cases and small and more gelatinous in those of longer standing. In the more chronic form it was hard and cheesy and somewhat difficult to cut. In a large number of cases the umbilicus did not seem to heal properly, and a partially healed opening remained which usually emitted a bad odor.

The post-mortem appearances were again described by Rettger and Stoneburn (35) in 1911 and in 1912 (39). Post-mortem examinations made of chicks dead from the disease, reported by Gage (37) in 1911, confirmed the findings of Rettger and Stoneburn. The yolks were unabsorbed in all but three cases. In an outbreak in Indiana reported in 1921, Spray and Doyle (84) found an enlargement of the liver, together with petechiae and necrotic foci in the liver and pneumonia and yellow friable nodules in the lungs, to be characteristic. Abscesses in the ceca were occasionally found. In 1924, Beaudette (117) reported the finding of a very noticeable yellow color of the liver, an unabsorbed yolk sac, and a bright red color of the lungs.

In 1925 Beaudette (174) reported the finding, in 1924, of small caseous nodules in the lungs of a large number of affected chicks. He pointed out that, while this lesion had been reported before, it seemed to have been overlooked by a number of investigators. In a large number of chicks affected with white diarrhea between the ages of 2 weeks and 3 months, he found peculiar lesions, consisting of nodules on the heart, which had not hitherto been described. In some of the cases only one large nodule was present, while in others a number of small nodules were observed. In most cases these nodules contained a white semifluid material, from which a pure culture of *B. pullorum* was isolated, and a similar culture was obtained in these cases from the heart's blood. In a very few instances these nodules were found on the serous surface of the breast bone, as well as on the gizzard.

Microscopic—Chicks.—The microscopic appearances were first reported upon by Milks (19), in 1908, who found the liver to have the most pronounced lesions. In 1911, Jones (34) reported finding congestion in the lung and sometimes hemorrhage into the bronchiols. In the liver there was usually a marked congestion, cloudy swelling, and fatty degeneration, and often small foci of necrosis; in the kidney parenchymatous degeneration in the cortex and medulla, congestion in the capillaries between the tubules, fibrin

in the tubules; the spleen usually congested; and in the intestines there was usually a degeneration of the mucosa, but almost no congestion.

In a histopathological study of the intestines of young chicks, reported by Gage and Martin (61), in 1916, cultures from several sources produced typical bacillary white diarrhea, and death resulted from 3 to 10 days after the inoculation. Stained sections were made from various levels of the intestinal tract of the dead birds, a study of which revealed marked injury to the mucosa, associated with hyperemia, hemorrhagic exudation, and leucocytic infiltration. In the individuals in which the disease had run a longer course there were exhibited processes of regeneration. There was in many instances a thickening of the intestinal wall. There was a marked fibroblastic proliferation, and wherever any of the columnar epithelium was intact there was active secretion of mucus. It was concluded that with these pathological conditions associated, and with repeated observations confirming them, it is evident that the important histopathological conditions in the intestines in young chicks dead of *B. pullorum* infection correspond to either an acute or beginning chronic condition of catarrhal inflammation.

Macroscopic—Adults.—Rettger and Stoneburn (35) in reporting on chronic cases, in 1911, stated that no matter how badly infected the ovary might be many of the ova were apparently normal. Little or no change of shape was observed in the small pathological ova, but they were more or less discolored and frequently showed slight changes in texture. The larger infected ova, however, often presented striking variations in shape and texture. They were frequently decidedly angular, and varied in their consistency from soft and liquid to firm and cheesy. There were various degrees of discoloration. At times the ova were found to be of a peculiar bright yellow, while again they might be quite dark, almost black, and occasionally more or less mottled.

The post-mortem findings in acute cases were first described by Jones (40) in 1913, then by Hadley (73) in 1917, and by Gwatkin (160) in 1925. The heart was observed by Jones to be enlarged and congested in some cases, the muscles containing round grayish white nodules varying from 2 to 12 millimeters in diameter. The pericardial sac was surrounded with a mass of yellowish white gelatinous exudate. The liver was enlarged, softened, the surface

sprinkled with minute grayish white areas of necrosis, with some fibrinous exudate present on the surface. The spleen was sprinkled with minute grayish white areas of necrosis. The surface of the pancreas had a number of tiny grayish white foci of necrosis. The kidneys were congested and very soft. The lungs were mostly normal. The ovary was congested, with irregular shaped retention cysts. In 75 per cent of the carriers the ovary was found to be cystic. In the intestines the duodenum was congested in some cases. Pure cultures of *B. pullorum* were obtained from the pericardium, liver, spleen, and ovary. The findings in a fowl examined at the Rhode Island station were described by Hadley (73). Gwatkin (160) found the lungs to have nodules and necrotic areas and some to show considerable inflammation, the findings being much the same as those of Jones.

Microscopic—Adults.—Tissue from fowls examined was sectioned by Jones (40), in 1913, including the heart, kidneys, liver, and pancreas. In the heart the principal lesion consisted in two comparatively large areas of coagulation necrosis. The muscle surrounding the nodules had undergone parenchymatous degeneration. Edema and an infiltration of leucocytes and fibrin was also noted between the muscle bundles. The blood vessels contained polymorphonuclear leucocytes in excess. The condition found is known as fibrinopurulent myocarditis. In the kidney there was marked acute hyperemia, the glomeruli showing some evidence of cloudy swelling. The tubular epithelium was in an advanced state of parenchymatous degeneration and in some parts of the specimen had become necrotic. A large number of the tubules contained varying amounts of fibrin. Fatty degeneration was also present. The condition is known as acute parenchymatous nephritis. In the liver the capsule was thickened with a fibrinous exudate containing a few leucocytes and fat droplets. The blood vessels of the capsules were congested. The liver cells in the center of the lobules were necrotic, but those around the edges were in an advanced state of parenchymatous degeneration. The capillaries contained large numbers of leucocytes and red blood corpuscles. A number of smaller veins were surrounded by dense masses of polymorphonuclear leucocytes. Congestion of the larger arteries and blood vessels was marked. Some hemorrhage into the tissue elements was present. In a more advanced case, the lesions were

about the same, although the necrotic areas were more marked and more numerous. This condition is known as acute parenchymatous hepatitis. In the pancreas the capsule, like that of the liver, was thickened with a fibrinous exudate containing leucocytes and fat droplets. In the earlier cases, the epithelium of the acini near the blood vessels were affected with cloudy swelling. In these areas the cell outline was obliterated, and the nucleus was pale. The blood vessels were hyperemic. In the cases of longer standing the centers of some of the lobules were necrotic. The intralobular connective tissue was infiltrated with fibrin. This condition is known as acute pancreatitis.

DIFFERENTIAL DIAGNOSIS

The objective symptoms are quite similar to those of coccidial and aspergillar or mycotic "white diarrhea," the presence of soft, whitish droppings and similar symptoms in each case causing them to be grouped under the common term white diarrhea, as pointed out by Jones (34), in 1911. Bacillary white diarrhea is distinguished from the other two by its early occurrence, the exceptional mortality, and the absence of the characteristic lesions of coccidiosis and aspergillosis, as pointed out by Ward and Gallagher (83), in 1920. Coccidiosis is slower in its development and usually affects chicks at a later period, and the coccidial cysts may be readily demonstrated by microscopic examination of the cecal contents. Aspergillosis, a mycotic disease, may be recognized by the characteristic fungal growth in the air passage and a microscopic study of it. The symptoms and lesions of fowl typhoid, due to *B. sanguinarium*, and acute *B. pullorum* infection of mature fowls are somewhat similar, and the organisms can only be differentiated by the biochemical cultural tests (see p. 107). Infection of the ovary by *B. pullorum* results in congestion and frequently the presence of hard irregular ova. Doyle (156) found a bacteriological examination to be the only reliable method of determining the presence of bacillary white diarrhea.

DIAGNOSTIC TESTS

Bacteriological.—The discovery by Rettger and Stoneburn (26, 35), in 1909, of the occurrence of *B. pullorum* in the yolks of eggs, followed by the finding of the organism in the ovaries of the hens that laid the eggs, led to bacterio-

logical examinations being made of the egg and the ovary as a means of detecting infection in laying stock (35). They pointed out that the examination of incubator eggs is far more practical than the examination of fresh eggs. The common method of direct inoculation of the culture media, at first employed, was superseded by an improved method for testing fresh eggs, reported by Rettger and Stoneburn (35) in 1911.

In experiments reported in 1912, Jones (38) demonstrated that such a low percentage of the eggs laid by infected hens contain *B. pullorum* that egg examination is not a practical method for locating a spreader of the disease. As the result of an investigation of the value of the egg test for *B. pullorum* as a means of diagnosis, reported in 1914, Gage (44) was led to conclude that the elimination from the ovary is so irregular that the egg test is impractical for rapid diagnosis.

Direct examination.—Rettger, Kirkpatrick, and Stoneburn (39) pointed out, in 1912, that direct examination of the ovaries of mature hens is an important method of detecting infection in a flock. The bacteriological examination of eggs and ovaries was at that time, however, considered to be the most satisfactory method of detecting infection.

Agglutination test of chicks.—Agglutination experiments with chicks were reported by Rettger and Harvey (18) as early as 1908. In a test made of the blood of chicks which had contracted the disease naturally, a slight agglutination was obtained in a dilution of 1 to 50. The blood of a chick which had received several injections of dead and living cultures gave an agglutination in dilution of 1 to 80 in 1 hour 7 minutes; 1 to 60 in 45 minutes; 1 to 40 in 12 minutes; 1 to 30 in 7 minutes; and 1 to 20 in 4 minutes. The blood of a rabbit given three injections of dead (heated) bouillon cultures, followed by three doses of living culture at intervals of 4 and 5 days, gave an agglutination in dilution of 1 to 80 in 35 minutes; 1 to 60 in 30 minutes; 1 to 40 in 25 minutes; 1 to 20 in 20 minutes. It was concluded, however (45), that this was impracticable in detecting the disease in chicks.

Agglutination test of adults.—The application of macroscopic agglutination to the detection of infection in the mature fowl was first reported and described by Jones (38), in 1912, who perfected and demonstrated its practicability a year later (41). He described the

method by which the test fluid is prepared, it being made in practically the same way as that used in the diagnosis of glanders. *B. pullorum* was grown on slant agar tubes at 37.5° C. for two or three days, and the growth then washed off with 0.85 per cent sodium chloride solution containing 0.5 per cent of phenol. The organism was then killed by heating to 60° C. for one hour, or the fluid may be used without heating. The suspension was then passed through cotton to strain out the clumps of bacteria. The carbolized salt solution was then added to the filtrate until it became faintly cloudy. Three cubic centimeters of the test fluid was then poured into a narrow tube, and the diluted blood serum added by means of a finely graduated pipette until the desired dilution was reached, and thoroughly mixed. The tubes were then incubated three days. A positive reaction consists of a clearing of the fluid and a clumping of the bacteria on the bottom and sides of the tube. When the test was applied, five fowls that were spreaders of the disease gave positive agglutinations with a dilution of 1 to 200, and one agglutinated up to 1 to 500. The highest agglutination of a normal fowl was 1 to 50, and the majority failed to agglutinate at all. Five cubic centimeters of blood was sufficient to make a complete test. The lower serum dilutions (1 to 50, 1 to 100, 1 to 200) were recommended for practical purposes. Jones found that the blood serum of all the infected fowls agglutinated at a dilution of 1 to 100; the serum of 91 per cent agglutinated at a dilution of 1 to 200, and 82.3 per cent agglutinated at a dilution of 1 to 500. Certain individuals gave a positive reaction with serum dilutions of 1 to 800, 1 to 1,000, 1 to 1,500, and 1 to 2,000. The best results were obtained with a test fluid made from several freshly isolated strains of *B. pullorum*. A test resembling the tuberculin test was experimented with, but fowls injected with the concentrated bouillon filtrate of a culture of *B. pullorum* did not show a rise in temperature.

An extended study by Gage (44) of the macroscopic agglutination test recommended by Jones, reported in April, led to the conclusion that it is a good laboratory method of diagnosis. Agglutinins from infected hens were found which reacted positively in dilutions from 1 to 100 to 1 to 5,000. Test fluids preserved on ice were found to keep in a very active state for more than two months. Rabbits were found to react to injections with pure

cultures of *B. pullorum*, and by very careful immunization yielded very active agglutinins, which were much more stable than from hens harboring the organism. Rettger, Kirkpatrick, and Stoneburn (45), in June, reported investigations of the macroscopic agglutination test as perfected by Jones, and described the method employed. They concluded that it furnished a reliable, inexpensive, and practical method of diagnosing ovarian infection in breeding stock. They pointed out that through its use a general campaign against the disease might be waged with every promise of success.

Gage and Paige (51), in 1915, reported in detail upon the application of the agglutination test to a number of breeding flocks. They urged the general adoption of this test as a means of eliminating the disease.

In 1916, Rettger, Kirkpatrick, and Jones (63) reported that a marked reduction on all but small flocks in the cost of the agglutination test was made possible by a simplification of the technique employed in the testing. Instead of making two transfers of the blood serum, as was done formerly, 0.03 cubic centimeter of the serum in the original blood tube was introduced directly into 3 cubic centimeters of the test fluid in which the final observations were made. A long series of tests with both methods showed that the results obtained with the shorter method were as exact and consistent as with the old. The modified method involved the use of 3 cubic centimeters of the test fluid (suspension of *B. pullorum* in carbonized physiological salt solution), but since the test fluid could be more readily prepared than when Witte's peptone was used in the culture medium on which the organism was grown, this should constitute very little of a drawback. On the other hand, much time and labor were spared in the actual testing technique and in the washing of test tubes. This work led Jones (70) to conclude that satisfactory tests can not be made until hens have passed one year of production.

Thompson and Dodson (92), of the New Jersey stations, in March, 1922, stated the discovery and development of the blood agglutination technique to be one of the greatest contributions to the science of poultry-disease control. By the application of the test to a breeding flock of 100 hens, 9 carriers were detected, the removal of which eliminated the chick loss. In investigations reported by Gage (93) in August, agglutination tests to the number of several hundred demonstrated an interagglutin-

ability of *B. pullorum* with *B. sanguinarium*, *B. typhosus*, *B. paratyphosus A*, and *B. paratyphosus B* antigens. Since 924 infected hens were detected among 5,619 hens in 20 flocks, he concluded that, when carefully controlled through epidemiological work, it is the best method of locating *B. pullorum* infection.

The fact that blood sera of heavy laying hens gives unsatisfactory results in the agglutination test led Hitchner (104), of the Maine station, to conduct investigations in 1923, which showed that a period of starvation of at least 36 hours previous to bleeding reduced the high fat content of the sera and resulted in clear sera and excellent tests.

In 1923, Beaudette (107), then at the Kansas station, reported the finding of agglutinins for *B. pullorum* in the albumin of eggs laid by infected hens, all but 1 of 10 infected birds used in the investigation showing this characteristic. Agglutination was found to be most marked when a 1 to 8 dilution of egg albumin was used. In 1925 (149), he pointed out, however, that since all carriers do not produce eggs containing such agglutinins it can not be relied upon. He also described (108) a single-tube method for making the agglutination test which differs from the old routine method in that a drop of serum is used instead of a graduated amount. The drop of serum is placed in 4 cubic centimeters of highly diluted antigen, which gives a dilution of from 1 to 80 to 1 to 100. Because of its greater dilution, less than half as much antigen is required, and the time required for incubation is reduced by at least 24 hours. In 1924 Beaudette (123), at the New Jersey stations, recommended that, in order to avoid fatty material or cloudy serum, fowls be starved for 24 hours preceding the bleeding, and pointed out that it was desirable to test the fowls while they are in low production or even while in a molt. Investigations, conducted at the Michigan station by Stafseth (165), of the agglutination test with special reference to cloudy reaction, extending over three years, showed that the food consumed is not in any way related to the reaction. Males never showed cloudy reactions, and it is thought quite possible that the cloudy reactions may be due to metabolic changes associated with reproduction.

Blood agglutination tests at the Lister Institute, reported by Knight (126) in 1924, led to the conclusion that the disease can be controlled by removing birds that have reacted to the aggluti-

nation test from the breeding pens. In July, 1925, Brunett (146) gave a detailed description of the technique employed in making the agglutination test. It was pointed out by Beaudette (149), in September of the same year, that a positive agglutination test does not indicate infected ovaries in all cases, as the infection may be located elsewhere in the body, and also that young fowls may retain the agglutinin but not the infection, from having had the disease as chicks. Doyle (156), however, in December, basing his view on the results of bacteriological examination of a considerable number of reactors, stated that with this disease the agglutinin appears to indicate present infection, reacting birds always having an infection of the ovary.

In a study, reported in October, of the agglutinability of 47 strains of *B. pullorum* from Michigan, Mallmann (151) found some to be quite consistent in their relations to the sera studied, while others were extremely erratic. He considers it advisable, in using strains of *B. pullorum* for antigen, to select only those strains that show high titers toward all sera used, and that are consistent. He found that *B. pullorum* antigen prepared for the agglutination test can be kept generally about 12 months in a refrigerator at a temperature of approximately 10° C.

The agglutination test, resembling the Widal test for the diagnosis of typhoid fever in man and the tests applied for glanders in the horse and for bovine infectious abortion, is the method now generally employed in detecting infection in adult fowls. Beaudette (149), of the New Jersey stations, stated, in 1925, that it was generally accepted that a bird, the blood serum of which agglutinates the organism at a dilution of 1 to 100, is infected. The same year Doyle (156) stated that in Great Britain and in America agglutination in a dilution of 1 to 33 is considered to signify infection, and in Great Britain in a dilution of 1 to 50 or in lower dilution as doubtful. He stated that, as a result of recent work, he regarded complete agglutination in a dilution of 1 to 25 as a positive reaction.

Intradermal tests.—In 1917, Ward and Gallagher (67) reported upon an intradermal test for *B. pullorum* in infected fowls which they considered to show sufficient promise to warrant further extensive trials in the field in comparison with the agglutination test. They found a killed culture of *B. pullorum* grown for about a month and held for

several weeks before use and without further treatment other than carbolizing to give the most satisfactory results. The diagnostic fluid was injected into the dermis of the wattle, and an edematous swelling appeared in infected birds in from 24 to 48 hours. The ophthalmal, palpebral, and subcutaneous tests failed to produce a reaction. Experiments with the intradermal test, reported on by Scherago and Benson (79), of Cornell University, in 1919, led to the conclusion that it is so inconsistent as to be worthless as a diagnostic agent for *B. pullorum* in adult fowls. It was found that foreign protein introduced into the dermis might bring about a reaction which would vitiate the test.

Experiments reported by Fuller (134), of Cornell University, in 1923, led to the conclusion that, while the intradermal wattle test is much simpler and easier to perform than the agglutination test and detects a large percentage of infected individuals, it does not detect them all in heavily infected flocks. He pointed out that only a very small percentage of noncarriers react to the test. Brunett (146), of Cornell University, stated in 1925 that, while the intradermal wattle test had not been used very extensively, it appeared to have some merits.

SYMPTOMS

Chick.—The disease in the chick, as described by Rettger (2) in 1900, first showed itself by a loss of appetite and sluggishness; the feathers then became rough and diarrhea prevailed. Later the chick remained standing in one place and refused to eat, at which stage the wings were drooped and ruffled, and the chick became very poor, its neck and legs appearing unusually long and slender. As the disease progressed the chick became very sluggish and finally was unable to stand, and lay on one side with wings outstretched as if utterly exhausted. The throat and mouth seemed normal, and at no time did the chick show any signs of pain. He reported in 1901 (3) that in the first stages the chicks seemed to be feverish and more or less thirsty, and the progress of the disease was more rapid. Milks (19) reported in August, 1908, that the course of the disease was so rapid that many chicks died during the night without previously having shown any signs of illness. In others the symptoms described were similar to those reported by Rettger.

W. R. Graham (17), in March, 1908, described the symptoms as appearing on the fifth day, usually with a thin

white discharge from the vent, though sometimes absent, inactivity and a sleepy appearance, with the head settling back toward the body. Some chicks search for the warmest spot under the hover, others have an intense thirst. Death took place in large numbers between the fifth and tenth days, continuing up to the end of the sixth week. A few chicks appeared to recover, but seldom, if ever, made good birds, remaining small and unthrifty. The symptoms in the epidemic and the induced infection observed by Rettger and Harvey (18) in May, 1908, with the exception of the occurrence of lesions at the point of inoculation, a longer duration of illness, and in a few cases labored breathing, were the same as those observed by Rettger in the epidemics of 1899 and 1900 and experimental infections.

In July, 1909, Rettger (24) and, in December, Rettger and Stoneburn (26), pointed out that the symptoms may vary to a certain extent in different epidemics and in the individuals affected, due probably to a difference in the virulence of the bacilli or to the varied susceptibilities of the chicks. In each case, however, the rapid emaciation of the chicks and the whitish diarrheal discharges from the intestines were most prominent. Rettger and Stoneburn pointed out that the characteristic whitish discharge from the vent soon makes its appearance in the flock, the time depending upon the virulence of the organism and the mode of infection. The discharge may be slight or profuse, in color white or creamy, sometimes mixed with brown. The voided matter has a more or less sticky or glairy character, and the discharge may simply streak the down below the vent or may cling to the down in sufficient quantity to seal up the vent and bring about a condition known to poultrymen as "pasting up behind." The wings soon begin to droop or project slightly from the body, with the feathers ruffled. In acute cases the eyes are closed and the chicks become indifferent to what goes on about them. Many of the chicks peep or chirp constantly, the sound being shrill or weak, according to the strength of the individual, and frequently, when endeavoring to void excreta, the chicks utter a shrill twitter, apparently a cry of pain. The breathing may be labored, the abdomen heaving with each breath, and occasionally one may note a certain amount of gasping or gaping.

Jones (34) reported in February, 1911, upon symptoms observed in New York State, pointing out that in chronic

cases the legs appear to grow, but that the body does not, the appearance being referred to as "short backed." In ingestion experiments by Rettger and Stoneburn (35), in April, 1911, many of the day-old chicks which ingested 4 to 6 drops of a 24-hour bouillon culture of *B. pullorum* on the fourth day appeared listless, with a loss of appetite and a tendency to remain huddled in the brooders. At the end of one week the infected chicks had made no gain, while the others had increased fully 25 per cent. The infected chicks were stunted and never reached normal size. The symptoms were described by Rettger in 1914 (46) as those of acute bowel trouble, namely, diarrhea, listlessness, loss of appetite, subnormal temperature, and extreme weakness, especially in the later stages.

The period of incubation for the disease was said by Ward and Gallagher (83), in 1920, to be from 4 to 10 days. They include a lack of vitality, small stunted body, drooping wings, and a narrow, contracted appearance viewed from behind, as described by Lewis (88). The disease, according to Kaupp (98), is manifested by a frothy, white to whitish brown, pasty discharge from the bowel, which adheres to the vent fluff.

Adults.—The symptoms of the acute form in the adult, as observed by Jones (40) in 1912, were, first, a paleness of the comb and visible mucous membrane, the comb appearing to be shrunken, scaly, and gray in color. The fowls appeared listless, and as the disease advanced depression became marked, with the head down and the wings sagging. The appetite was lessened, and diarrhea was usually present, the tail feathers being soiled with yellowish white feces. Similar symptoms were observed by Gwatkin (160). Cases of adult infection with *B. pullorum* with symptoms similar to those of fowl typhoid were observed at the Kansas station (132).

COURSE

The disease is classified as an adult and chick infection, and appears in both acute and chronic forms, as described by Brunette (146) in 1925. In the chick it appears in the acute form as a result of infection in the egg or through contamination in the incubator or brooder in the early hours of life. It was observed by Milks (19) that the course of the acute form in the chick may be so rapid that many may die during the night without previously having shown any signs of illness. Canfield (148) pointed out that while the

disease may prove fatal at any age, by far the greatest loss occurs among chicks from 4 to 16 days old. The chronic form in the chick is apparently due to a late infection from contaminated brooders or to an early infection with an organism of comparatively low virulence.

In the adult it is the chronic form, in which the infection is localized in the ovary, and the hen becomes a carrier transmitting the disease through the egg to the chick, that is commonly met with. The occurrence of the acute form as a septicemia in the adult fowl has been reported by several authors, including Jones (40) in New York State, Hadley (73) in Rhode Island, and Gwatkin (160) in Ontario. In origin this form may be endogenous, arising from an infection of the ovary, or exogenous, arising from the eating of eggs infected with the organism. In the adult the disease was observed by Jones (40), in 1912, to run a variable course, sometimes terminating fatally in 24 hours, but usually running a regular course of 4 or 5 days and sometimes even longer. The period of incubation varied from 16 days to 3 weeks. A variable course was also noted by Gwatkin (160), sometimes terminating fatally in 24 hours, but usually running a regular course of 4 or 5 days or longer.

NATURAL INFECTION AND TRANSMISSION

Experiments reported by Rettger and Harvey (18) in 1908, in which bouillon cultures of the organism were ingested by an 8-day-old and a 10-day-old chick, first demonstrated the possibility of infection when taken into the gastrointestinal tract. It was pointed out that this might serve to throw some light on the natural mode of infection, namely, from chick to chick through feces-contaminated food or drinking water.

The investigation of Rettger and Stoneburn (26), reported in 1909, led to the conclusion that the mother hen is the original source of infection of the chick. It was found that a certain percentage of the chicks on infected farms have the disease when hatched; further that the disease may be induced by subcutaneous injection of chicks with pure culture of the organism, and transmitted through infected food supply. In 1909, Rettger (24) stated that sufficient evidence was at hand to show that chicks may acquire the disease through food and water that have become infected.

In 1911, Jones (34) reported experiments from which he concluded that

the disease is transmitted in three ways: (1) Through the egg, (2) by direct contact in the incubator with individuals that have acquired the disease through egg infection, and (3) by day-old chicks being placed in contaminated surroundings. He pointed out that, while the probable number of eggs infected with *B. pullorum* is small, a chick hatched from an infected egg could infect a whole hatch. Rettger and Stoneburn (35) concluded, in April, that female chicks which survive often harbor the infection and may become bacillus carriers, infection in the breeding pen being perpetuated in this way. A diagram was given illustrating the manner in which the disease perpetuated itself in breeding stock. They reported that noninfected hens kept with infected hens apparently did not contract the disease.

The investigation reported by Jones (38) in 1912, showed that often, for comparatively long intervals, spreaders may not lay eggs containing the specific organism. Two newly hatched chicks were covered with a fluid containing *B. pullorum* and placed first in an incubator and then in a brooder with 36 that had just hatched, and during the following 4 weeks 11 of the chicks died of the disease. In 1914, Rettger, Kirkpatrick, and Stoneburn (45) reported further experiments showing that surviving chicks may become permanent carriers. A further account was given by Rettger (46), in 1914, of ovarian infection and direct transmission to the offspring.

Rettger, Kirkpatrick, and Card (77) pointed out, in 1919, that the spreading of infection from chick to chick apparently ceases after the age of 3 or 4 weeks. They found maturing and adult hens to be susceptible to infection from without, the rapidity with which such infection spreads varying with different flocks. In some instances the rates of spread within 12 to 15 months might be 20 or even 25 per cent of the entire flock. The results of experimental work, contrary to those of previous experiments (39), strongly indicated that transmission of infection from hen to hen through infected litter and by ordinary contact and association rarely, if ever, occurs, but indicated that the infection of pullets and fully mature hens may be brought about readily by infection of the cloaca and lower end of the oviduct. The conclusion was reached that males should not be allowed to run with the females except during the breeding season, because of the probable passive transmission from hen to

hen. They concluded that testicular infection is too rare to play a significant part in the transmission of the disease from the male to the hens, and that the possibility of transmission of infection from hen to hen through the agency of the male as a passive carrier is of vastly greater importance. They considered circumstantial evidence of such transmission by the male to be so great that its transmission in this way could not be doubted. It was considered quite probable that *B. pullorum* is expelled from an infected ovary from time to time in appreciable numbers, and particularly when there is a rupture of one or more of the small infected ova, or during their reabsorption. The question of transmission of infection from the hen to the male was thought to require further investigation before a definite conclusion could be drawn.

Doyle (156) reported, in 1925, an experiment in which 50 naturally infected carrier adult fowls and 30 healthy controls were housed together in several pens for the period of one year, and none of the controls became infected, as was determined by monthly agglutination tests. It was pointed out by Canfield (148), in 1925, that affected chicks which survived seldom succeeded in freeing themselves from infection, remaining carriers as long as they lived.

PROGNOSIS

Chicks.—That a few chicks appear to recover, but seldom if ever make good birds, was the opinion expressed by Graham (17), in 1908. He had found chicks to remain small, unthrifty, and good subjects for roup or any other epidemic to which chickens are subject. In 1909, Rettger and Stoneburn (26) stated that a large percentage of infected chicks died under 4 weeks of age, and that those that survived the infection were weak and stunted and seemed particularly susceptible to other disorders. Beaudette and Black (172) state that about 25 per cent of the chicks which recover retain the infection, and that such infection may hinder growth for a few months, but after such period they show no physical signs of having had the disease.

Adults.—The possibility that a reacting hen which lays eggs the yolks of which contain *B. pullorum* may recover and no longer react is shown by the history of a hen reported by Horton (64), of the Missouri poultry station, in November, 1916. A bantam hen, in a flock of several hundred birds of which

65 per cent were infected, was found through the agglutination test, in December, 1914, to be infected, the infection being of ovarian origin, since pure cultures of *B. pullorum* were isolated from two unhatched eggs of a setting laid by this bantam in 1915. In the fall of 1915 the reaction was faint after 72 hours, and during 1916 two tests were made, both of which were negative even after 72 hours.

Doyle (156) found by means of monthly agglutination tests that of 14 carriers which had presumably acquired the disease in the chick stage 77 per cent were still infected at 2 years of age, and that 21 per cent of those which were infected up to the age of 12 months recovered during their second year. A bacteriological examination of the recovered fowls gave negative results. He concluded that the number which recover is too small to be of practical importance. Of 42 carriers examined, *B. pullorum* was isolated from 88 per cent, and pathological changes were found in the ovary of 69 per cent. While some writers state that a carrier may make a complete recovery in the course of two months and be safely used for breeding purposes, Doyle concluded, from the extensive pathological changes in the ovary of 29 of the 37 fowl, that it is unlikely that they ever make a complete recovery.

TREATMENT

The finding of *B. pullorum* in the crop in large numbers led Rettger (24), in 1909, to suggest that the feeding of well-soured milk at least two or three times a day would probably render the crop, stomach, and upper portion of the intestine sufficiently acid to hold the organism in check or even kill it. In an experiment conducted by Jones (38), in 1912, sulphocarbonates and creosote were fed in mash twice a day to 1-day-old and to 10-day-old chicks that were given 15 cubic centimeters of a 48-hour bouillon culture of *B. pullorum*. The results indicated that neither were of any great therapeutic value in the treatment of the disease. An extensive investigation of the value of sour milk in combating the disease was reported upon by Rettger, Kirkpatrick, and Stoneburn (39) in 1912—Hodge having previously recommended its use with quail and grouse. In all but two of seven experiments conducted its beneficial effect was demonstrated. In every instance the mortality was lower in broods which received sour milk than in the corresponding broods that did

not. The milk was given to the chicks early in life and kept constantly before them. Bushnell and Maurer (42), of the Kansas station, reported in November, 1913, on feeding experiments with cultures of *Bacillus bulgaricus* which failed to show any superiority over ordinary sour milk. Their findings corroborated the more exhaustive studies of Rettger, Kirkpatrick, and Stoneburn. The sour milk had a beneficial action when given 40 hours before infection.

Jones (43) reported in 1913 that he had failed to obtain any beneficial results from the use of sulphocarbonates and creosote. In 1912 (171), 1914 (163), 1917 (74), and 1922 (98), Kaupp recommended the use of mercuric chloride at a dilution of 1 to 10,000 with sulphocarbonates of zinc, sodium, and calcium. Horton (47) reported work at the Oregon station in 1914 in which 50 chicks received the sulphocarbonate treatment, only 7 remaining alive at the end of 10 weeks. He concluded that, from the manner in which the chicks died off and from the appearance of the 7 that survived, the sulphocarbonates had very little if any efficiency. Rettger, Kirkpatrick, and Stoneburn (45), in an investigation of the carrier problem, reported in 1914, found the feeding of sour milk to infected chicks to reduce the percentage of bacillus carriers. Milk soured by *B. bulgaricus* was found to possess no distinct advantage over naturally soured milk. Rettger, Kirkpatrick, and Card (50) reported, in 1915, investigations which showed that, if fed soon enough and for a sufficiently long period, milk greatly reduces the death rate from bacillary white diarrhea. Sweet and sour milk appeared to be of equal value in their relation to growth and mortality. Jorgenson (116) reported briefly in 1924 upon a few tests which indicated that milk cultured with *B. acidophilus* prevented the disease in exposed field chicks and had a favorable effect on the course of the disease.

Beach and Freeborn (94), of the California station, pointed out, in 1922, that there is no satisfactory method of treating the disease, drugs being of no value for this purpose. In investigations of the influence of various dilutions of lactic acid, reported by Kaupp and Dearstyne (150), of the North Carolina station, in September, 1925, *B. pullorum* was found to have a limit of tolerance to lactic acid between 0.6 and 0.7 per cent. Canfield (148), in 1925, pointed out that there appears to be no therapeutic treatment that

has very much practical value. Beau-dette (17) stated, in 1924, that treatment is of no value, should not be attempted, and that the chicks should be killed. Doyle (156) stated, in 1925, that attempts to cure affected chicks are futile and inadvisable, that, in spite of the many so-called cures on the market, there is no method of treatment yet discovered that is of the slightest value. The fact that many chicks which recover are potential sources of future outbreaks is a strong argument against the policy of treatment. Hinshaw (153) pointed out, in 1925, that, while the use of sour milk and medicinal agents may be of some value in prevention, curative measures should not be attempted in most cases.

PREVENTION

The perfection of the macroscopic agglutination test (see p.114) for detection of infected fowls by Jones (41), in 1913, has made it possible to eliminate the infection from a flock, and this is now recognized as the only satisfactory means of prevention. Many supplementary measures have been recommended.

In 1908, Rettger and Harvey (18) reported that through cleansing and disinfection of incubators and brooders, as well as inclosures in which the chicks are kept, are the best safeguards against the disease. The importance of increasing the resistance of the chick by preserving its vitality through proper feeding was also emphasized. In 1909, Rettger (24) referred to isolation of the birds, as well as disinfection of the incubators, brooders, poultry yards, etc., as preventive measures.

Jones (34), in 1911, presented experimental evidence to show that chicks may become infected by being placed in contaminated quarters, 12 of 18 chicks thus exposed having become infected, and at the end of three weeks the mortality was 44.5 per cent. The importance of disinfecting the brooders was demonstrated, since the disease did not develop in an infected pen that was completely cleaned and treated. The necessity for burning used litter; disinfecting houses, floors, and runways; and scalding feeding and drinking utensils was pointed out. Practical suggestions for prevention were made by Rettger and Stoneburn (35) in 1911, and in 1912, Rettger, Kirkpatrick, and Stoneburn (39) expressed the opinion that it should be both a moral and legal offense for persons to sell or exchange eggs, chicks, or

mature stock which come from flocks that they know to be infected with the germ of bacillary white diarrhea.

Breeding for resistance is under way at the Illinois station (155, 159).

IMMUNITY AND IMMUNIZATION

In investigations reported in 1915, Smith and TenBroeck (49) found that the bacterium-free filtrate of 5-day to 15-day-old bouillon cultures of *B. pullorum* were decidedly toxic to full-grown rabbits when given by intravenous injection. Death followed within two hours, or there was marked dyspnoea followed by death overnight or by loss of weight and subsequent recovery. The lesions induced included congestion of the liver, lungs, spleen, kidneys, adrenals, mesenteric lymph glands, and trachea, dilatation of the heart, and hemorrhage into the gastric mucosa. Immunization experiments with the disease were first conducted by Rettger and Harvey (18) in 1908. A chick which received subcutaneous injections at 8-day intervals of 0.25 and 1 cubic centimeter of bouillon cultures which had been heated at 60° C. for 10 minutes remained apparently normal. No noticeable protective action was established, as the chick died on the sixth day after injecting a live culture of the organism. A rabbit was given subcutaneous injections of 0.5, 1, and 1.5 cubic centimeters of bouillon cultures, which had been heated at 60° for 10 minutes, at intervals of six and eight days. No signs of discomfort or lesions developed, and after subsequent injection of living culture prominent lesions occurred, but the rabbit remained normal in other respects. No definite conclusions could be drawn.

A bacterine made by Jones (38), in 1912, from a suspension of *B. pullorum* which had been killed by heating to a temperature of 60° C. for two and one-half hours did not produce any marked immunity in susceptible chicks. He considered it to have demonstrated that vaccines made from dead cultures of *B. pullorum* are not of any value in the prevention or treatment of the disease. Gage pointed out in a personal communication to Rettger, Hull, and Sturges (58)—reported in April, 1916—that rabbits are very susceptible to subcutaneous administration of even small doses of *B. pullorum*, and for this reason it is very difficult to immunize them to this organism.

Jorgenson (116) reported in February, 1924, that a serum from rabbits immunized with cultures of *B. pullorum*, when

fed twice a day in 5 cubic centimeter doses to chicks ill with bacillary white diarrhea and to well chicks exposed to the infection, apparently modifies the course of the disease and in healthy chicks serves to protect against it. It should be pointed out that this conclusion is based on a very limited number of tests.

Doyle (156) reported, in 1925, that the toxins produced by *B. pullorum* conferred no protection on rabbits, fowls, or chicks against artificial infection. He considered vaccines useless, as they confer no protection during the susceptible period, and the danger of acute infection has passed before immunity is acquired. Chicks that were given small doses of serum from a sheep hyperimmunized against three strains of *B. pullorum* contracted the disease in the same time as untreated controls. He stated that, although some workers may have reported favorably on the use of serum from hyperimmunized fowls, the inoculation of day-old chicks is not a practicable proposition, since they are far too delicate and fragile to permit of such intervention as a routine measure.

ELIMINATION—CONTROL

The investigations of the etiology of this disease have shown that control work must primarily be aimed at elimination of infected breeding stock. For detection of carrier fowls, the agglutination blood test perfected by Jones (41) in 1913 has been found most satisfactory and is now being quite generally employed. In reporting, in 1914, upon investigations of the agglutination test, Rettger, Kirkpatrick, and Jones (45) pointed out that, with the perfection of this test, a general campaign against the disease could be waged with every promise of success by applying it to breeding stock. They expressed the hope that Connecticut would be the first to conduct such a campaign. In 1915, Gage and Paige (51) reported investigations which led them to urge the organization of a campaign to eliminate the disease from breeding flocks in Massachusetts, in which the agglutination test would be adopted as the means of diagnosis.

Later, in 1915, Rettger, Kirkpatrick, and Jones (54, 55) reported upon a campaign against the disease that had been inaugurated in Connecticut in June, 1914, in which efforts to eradicate the disease were based entirely upon the results of agglutination tests. During the first year of the campaign, 13,831

hens in 107 flocks were given the macroscopic agglutination test, of which 10.24 per cent were found infected, as were 2.9 per cent of the 786 males tested. The retesting of flocks which on the first examination by this method contained carriers and from which the reactors had been removed gave widely different results. In 4 flocks out of a total of 13, no reactors were found at the time of the second test, but in the other 9 the percentage of infection varied from 0.6 to 25.7, the number in each instance being decidedly less than in the first test. The breeding records obtained from the owners were most encouraging, and, with few exceptions, showed a large percentage of successful rearings as compared with previous years.

In 1916 Rettger, Kirkpatrick, and Jones (63, 70) reported upon the second year of the campaign, in which 7,799 fowls were tested. Of the 6,262 fowls in 78 flocks tested for the first time, 8.2 per cent were infected and 1.4 per cent doubtful. All of the 1,441 fowls retested during the year gave negative reactions, though the flocks to which they belonged contained positive reactors. All of 157 males tested, including 61 retested males in infected flocks, gave negative reaction.

Control work was started in New Hampshire in 1918, when 4,000 samples were tested and 11,000 the following year, 10 cents per bird having been charged for making the test, the work being self-supporting. It was stated in 1921 (85) that, as a result of the tests, the loss of chicks from stock which had been tested was 29 per cent less than in previous years, when no testing was done. Many poultrymen reported losses as high as 60 per cent of all chicks hatched before the testing was done, whereas losses after testing ran as low as 5 to 8 per cent. Of 13,059 birds in 60 flocks tested in 1920, 60 per cent of the flocks and 7.66 per cent of the birds were found infected. Forty thousand birds were tested in 1922-23 (112).

In Massachusetts the work of inspection of breeding flocks to determine the presence of the disease, reported by Gage and his associates (91, 95, 102, 125, 145), was commenced in 1920-21, under a law enacted in 1919. From 24,718 fowls in 116 flocks tested in 1920-21, the number tested increased yearly until in 1924-25, when 66,503 in 156 poultry plants were tested. The percentage of reactors decreased from 12.5 in 1920-21 to 2.94 in 1924-25.

In an attempt to determine the prevalence of the disease in Kansas, the

station (124) tested 10 birds picked at random from each of 74 flocks in 13 counties located in different sections of the State. About 78 per cent of the flocks contained reactors, and 31 per cent of the birds examined were infected. Of 2,152 birds from 90 flocks in 25 counties, 38.3 per cent reacted. In work conducted by the Delaware station (136) in 1922-23, 9.2 per cent of 1,034 birds tested in 4 flocks reacted, and in 1923-24, 8.3 per cent of 1,868 birds in 9 flocks reacted.

Newsom (129), of the Colorado station, reported that of 1,394 fowls tested in 1924, 23 per cent reacted. Feldman (157), of the same station, reported a reaction of about 10 per cent of some 11,000 birds tested in that State during a period of 6 months in 1925.

Late in 1921, the Michigan station (87) announced that it was ready to make agglutination tests and examine diseased fowls for *B. pullorum*. In 1924 that station (114) published a map which showed the disease to be very prevalent in the more densely populated sections and to have become widely distributed over the lower peninsula. In the testing work conducted, 365 of 2,779 fowls examined in 1921-22 (97) were found infected, as were 1,792 of 5,059 fowls examined in 1922-23 (109), and 1,750 of 9,162 fowls examined in 1923-24 (165). Stafseth (165) of that station emphasized the importance in control work of constantly culling birds which show signs of disease. In support of this he refers to the case of a fowl that failed to react to a dilution of 1 to 50, in the abdomen of which an encapsulated abscess containing *B. pullorum* was found.

Merrill (139) reported that the disease was rather widespread in Maine, and was the cause of heavy losses to some poultrymen. During the year ended June 30, 1924, 13,145 samples of blood from 54 flocks were tested and less than 2 per cent found infected. It was pointed out by Canfield (148), of the Michigan station, in 1925, that, while the agglutination test to eliminate adult carriers is usually made some time before hatching season, once each year, until no reactors are found, some breeders get quicker results by testing twice each year, the first test being made during the fall or early winter and the second shortly before the hatching season. In Hancock County, Ind. (162), where some 10,000 hens in 30 flocks were tested in the spring of 1924, the percentage of reactors ranged from 2.3 to 57 per cent. A survey of 21 of these flocks showed that only 41 per cent of

16,109 chicks hatched were raised in 1923, whereas in 1924 64.6 per cent of 11,485 chicks were raised. The Illinois station announced in 1923 (103) that it was prepared to make agglutination tests. In 1925 it reported (158) that since October, 1923, the test had been applied to 363 flocks with 41,226 chickens, in 65 counties of the State. Of these about 13 per cent were infected, about 5 per cent were suspicious and probably infected, and about 80 per cent disease free. In some flocks the infection ran as high as 75 per cent, and only 2 of 363 flocks tested were found to be free. Of 50,480 birds from 391 flocks in 61 counties tested in 1924-25 (166), approximately 12 per cent reacted, only 5 flocks being found free from the disease. Clark (144), of Indiana, who in June, 1925, separated 3 flocks with a total of 617 birds and kept the reactors and healthy fowl under the same feeding and housing condition for periods of from 30 to 42 days, found the reactors to lay from 27 to 38 per cent fewer eggs than the uninfected fowl. Murray (169), of the Iowa station, reported that, of the 1,600 fowls in the Iowa College poultry flock tested in 1922, 30 per cent reacted and were removed. In 1923 but 3 per cent of the 2,000 tested reacted to the test, and in 1924 only five-twelfths of 1 per cent of the 1,200 birds tested were found infected.

In 1922, Gage and Flint (95, 102, 125, 145) outlined three plans for testing, any one of which could be used by poultrymen cooperating with the Massachusetts station in eliminating the disease from their breeding flocks. The first two called for a retesting of the non-reactors in 6 to 12 months, while by the third the test was applied twice to pullets and to their offspring before being bred. According to Hinshaw (153), the Kansas station has used the latter plan with encouraging results. The need for universal adoption of a standard method of conducting the test was pointed out, in 1925, by Hinshaw (153), who reported that birds having a serum with an agglutination of 1 to 20 are classed as carriers by the station. He considered the elimination of adult carriers, combined with a sanitary program, to be the ideal means for control. A simple but effective system of management for control of the disease was described by Waite (147), of the Maryland station, in 1925.

In New Jersey the control work, as announced by Beaudette (123), who gave directions for the collection of blood samples, was commenced in 1924

as a part of the certification program of the State Department of Agriculture, in cooperation with the New Jersey stations. A description of the methods employed, including technique, and of the problems met with in New Jersey was given by Beaudette and Black (172), in reporting the results of control work in that State during 1924-25. Of the 28,103 birds tested during the year, 6.43 per cent were found infected. The infection in pullets was slightly greater than in hens, but cock birds were more heavily infected than cockerels. In general, the heavy breeds showed a greater infection than the light breeds except where only a small number of birds were tested. It should be pointed out that 20,206 of these fowls were handled under the State certified-accredited flock plan, and that but 2.76 per cent of the certified birds were found infected.

In tests reported by Doyle (156) in 1925, 21 of 84 chicks artificially infected gave positive reactions to the agglutination test 1 year later, all reactors giving evidence of ovarian infection. Of 21 2-months-old chicks which had survived an outbreak, 57 per cent were found infected. In tests made of more than 1,000 young birds on a farm where the disease had caused a heavy mortality during the previous breeding season, 40 per cent were found to be infected.

In agglutination test work, Beaudette and Black used a drop of blood serum to 4 cubic centimeters of test fluid, as employed in the single tube method (108), the resulting dilution being somewhere between 1 to 80 and 1 to 100 (see p. 116). It is pointed out that the question of what dilution should be considered diagnostic is still unsettled, some laboratories considering complete agglutination in a 1 to 10 dilution diagnostic, while others use a 1 to 50 dilution. As further pointed out, it depends a great deal upon the turbidity of the test fluid. If the test fluid is sufficiently turbid, it might be possible to use a 1 to 10 dilution of serum, while, on the other hand, if the test fluid is only of slight turbidity a correspondingly high dilution of serum must be used. The authors believe, however, that there is less opportunity for false reactions to take place when a test fluid of only slight turbidity is employed. They emphasized the fact that, since practically all reacting fowls agglutinate the organism in at least a 1 to 360 dilution, the dilution which they used is a safe one. Although it is true that occasionally a serum may be found that will cause agglutination in only 1 to 40

dilution, this does not necessarily mean that the fowl carries an active infection. Agglutination in this dilution might in some cases indicate the beginning of infection in the case of mature birds, but to eliminate such birds as carriers would likely throw out a large number of normal individuals, since about 75 per cent of the chicks which recover from the primary acute infection never retain it localized in the ovary. They consider it quite possible that the agglutination produced in low-serum dilutions is due to the persistence of agglutinins after the infection has failed to become localized. This reasoning, as pointed out, is based entirely on the serum-antigen dilution used in their laboratory. In their tests, where reaction occurred, in only four or five cases did agglutination fail to be completed.

Rettger (166, 169) is quoted as stating that the time has arrived when an intensive concerted effort to eliminate bacillary white diarrhea should be made through the various States in cooperation with the Federal Bureau of Animal Industry. It is his opinion that testing and control work should be placed under institutional auspices, preferably those of the Federal Government and experiment stations. The more specific replies to a questionnaire on control of the disease, conducted by the poultry office of the Animal Husbandry Division of the Bureau of Animal Industry, were assembled and issued on July 18, 1925 (166, 169). Station men contributing to the questionnaire include Rettger of Connecticut, Gage, Flint, and Bransfield of Massachusetts, Bushnell of Kansas, Stafseth of Michigan, Craig of Indiana, Runnels of Virginia, Murray of Iowa, May of Rhode Island, Goss of Ohio, Dimock of Kentucky, Beaudette of New Jersey, Lipp of South Dakota, Connaway of Missouri, Fitch of Minnesota, and Van Es of Nebraska.

ACCREDITATION

With the application of the agglutination test and the elimination of infection from the breeding flock, a demand has arisen for the accreditation of disease-free flocks by the State. Illinois is stated by Newsom (129), of the Colorado station, to have taken the lead in officially accrediting flocks, the State veterinarian issuing the accreditation and supervising the control. The licensed veterinarians draw the blood and leg band the birds, for which a fee of 5 cents per bird is allowed. The tests are made for an additional 5 cents, and the culling is done by the

veterinarian who drew the blood. After two negative annual tests the flock is accredited, the owner signing a contract to follow hygienic regulations set down by the State veterinarian (173). Newsom points out that in some States the accrediting is done under the direction of an association of poultry raisers.

Merrill (139) reported, in 1925, that 23 flocks containing 7,798 hens were placed upon the Maine accredited list for the year ended June 30, 1924. Beaudette and Black (172), in their report of control work in New Jersey in 1924-25, emphasized the fact that the term "accredited" is used in New Jersey to indicate a disease-free chick, whereas in some States the same term is used only to indicate a chick produced by a flock that has been culled for type and egg production but has not been tested for white diarrhea. It was stated in 1925 (167) that in approximately one-half of the States there is now in operation some form of accreditation or certification plan or both.

A standardization conference was held at Manhattan, Kans., August 10-11, 1925, at which a uniform plan of accreditation and certification of poultry was adopted (170).

The work with *B. pullorum* as here reviewed would seem to support the conclusion of Beaudette (149), in 1925, that more is probably known about this disease than any other malady of the common fowl, and it would appear that a sound basis has been laid for practical control and even eradication.

In conclusion, the writer would call attention to the far-reaching effect that the investigations here related, conducted to a large extent by agricultural experiment stations, have had upon the poultry industry, the products of which, as pointed out by Director Shaw (154), of the Michigan station, are worth \$300,000,000 more than the wheat crop, or more than a billion dollars annually. This accomplishment stands as one of the most striking illustrations of the economic benefits that have resulted from research work at the agricultural experiment stations of this country. It is not too much to say that when the accreditation work, now in its infancy, has become universally adopted and the disease practically eliminated from the American poultry yard, the saving as a result will far exceed the total amount now appropriated annually for research work at the experiment stations. Homage should be paid to the many investigators that

have been engaged in and have contributed so unobtrusively to the solution of this great economic problem, and particularly to Rettger, F. S. Jones, Gage, and their associates, who led the way and have accomplished so much.

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STATION WORK ON THE MECHANICS OF TILLAGE

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INTRODUCTION

Studies of the cost of producing agricultural commodities have developed the fact that power, whether man, animal, or mechanical, is the most expensive necessary item in such production. Kinsman, of the Bureau of Public Roads of the Department of Agriculture (1),¹ has shown that more primary power is used in agricultural production at present than in any other industry with the exception of transportation. Investigations made in representative sections of the country have shown further that tillage operations, which are indispensable in crop production, are among the greatest consumers of power. Efforts are therefore being made by different stations to reduce the power consumption of tillage operations as a step of primary importance in reducing the cost of agricultural production.

A critical analysis of some of the tillage problems of crop production by Nichols at the Alabama station (2) led to the conclusion that seed-bed preparation and cultivation are processes whose efficiency depends largely upon the degree to which tillage implements are adapted to the physical and mechanical properties of the soil. Tillage, which consists primarily of these two operations, offers a complex power utilization problem, which has an obvious bearing on the cost of agricultural production.

SEED-BED PREPARATION

Proper seed-bed preparation implies the production of a certain type or degree of tilth in soil which is more or less specifically adapted to the requirements of the optimum germination and growth of a particular crop. However, standard agronomic classifications of soils, and agronomic methods of expressing soil conditions corresponding to specified degrees of tilth have been found to provide a generally inadequate basis for the development of equipment capable of producing the desired results.

Engineering properties of soil.—In order to produce any desired state of tilth

in a soil, it seems evident that certain engineering properties of the soil must be overcome to a corresponding degree. Such properties may be described as those physical and mechanical properties which directly influence the engineering operation of tillage as distinguished from those pertaining merely to certain conditions of fertility. In this connection Nichols at the Alabama station (2), Trullinger of the Office of Experiment Stations of this department (3), and others have brought out that such soil factors as cohesion, adhesion, plasticity, tensile strength, shearing strength, compressive strength, compressibility, moisture content, external and internal frictional characteristics, and possibly others, may quite materially influence the tillage operation. King at the Wisconsin station (4) showed, for instance, that plowing with the moldboard plow, the most widely used method in seed-bed preparation, involves the shearing, lifting, inversion, and pulverization of soil, all of which occur in opposition to the cohesive, adhesive, and frictional properties of the soil.

Tilth.—Some of the stations are endeavoring to devise methods for measuring standard degrees of soil tilth with the idea of specifically designating them for each crop or class of crops in terms of the engineering properties of any soil. The purpose of such work is to provide a more definite basis for procedure in studying the mechanics of tillage. Typical of such work is that by Hoffman at the California station (5), where, as a logical beginning, two general methods of measuring and designating the states of tilth of different soils, which are known to meet certain agronomic requirements, are being developed. The first of these involves the use of six screens placed one above the other, the top screen having an 8-inch mesh and decreasing in size down through 4-, 2-, 1-, and 0.5-inch sizes to the bottom screen which has a 0.25-inch mesh. The soil samples, weighing from 50 to 60 pounds and taken to the depth of tilth in an undisturbed condition, are gently deposited upon the top screen, and the percentage by weight retained by each screen is recorded. Only the 0.5- and 0.25-inch screens are

¹ Numbers in italics in parentheses refer to "References," p. 137.

shaken. Curves platted from such data so far permit the specific designation of the states of tilth in the different soils and indicate the tendencies of tillage operations in producing them. The second method measures the density of the soil before and after tillage, the resulting ratio indicating the degree of pulverization. It is understood that the work is being continued in order to measure these degrees of pulverization in terms of the engineering properties of the soils which largely govern their production.

The intensity of the resistance offered by the engineering properties of soils to their tillage is naturally the factor which governs the power requirement of the tillage operation. It has been comparatively easy to demonstrate that soils possess these properties, but attempts to evaluate them in terms of their specific influence upon the accomplishment of preconceived tillage results by the empirical testing of available tillage machines in the field, have met with relatively little success.

Plowing.—It seems generally accepted that plowing consumes more power than any other individual operation in seed-bed preparation. Attempts to reduce the power requirement to a minimum have naturally resulted in the special but nevertheless wholly empirical shaping of plow surfaces for various purposes, and have established the broad general fact that for this purpose, as well as to produce desired tillage results, different soils require different kinds and shapes of plows.

A lack of knowledge of the nature, intensity, and specific influence of the engineering properties of soil has greatly handicapped the work with plows. To begin with, their marked variations have materially influenced the power requirement of plowing. As far back as 1900 Burkett and Johnston found, in experiments at the New Hampshire station (6), that the same plow varied widely in draft under apparently the same visible soil conditions. In partial explanation of this Keen and Haines (7) showed, in experiments at the Rothamsted Experimental Station, that large variations in the resistance of a soil to plowing may exist over a short distance, regardless of chance changes in the implemental factors. Davies at the same station (8) showed in addition that the state of consolidation of the soil due to the nature and treatment of the previous crop had a most marked influence on the power required for plowing.

With reference to the influence of the individual soil properties, Ocock of the

Illinois station (9), working with turf and stubble moldboards, found that the ordinary moldboard plow had a heavier draft in soil which was extremely dry or very wet than it did in soil containing only a moderate amount of moisture. Davies at the Rothamsted Experimental Station (8) also showed that the moisture content had a marked effect on plow draft, and suggested that there is an optimum moisture content from which an increase or decrease will result in increased draft.

In an attempt to increase the efficiency of plowing, Davidson, Fletcher, and Collins found, in studies at the Iowa station (10), that an increase from 2 to 3 miles per hour in the field speed of a general-purpose moldboard plow resulted in an increase in the draft of from 8 to 12 per cent, according to the nature of the soil. Doubling the speed increased the draft from 16 to 25 per cent. Although the furrows were laid more smoothly and the furrow slices were better pulverized at the higher speeds, economy was sacrificed in the greater power requirement, since the plows used were apparently not designed to fully meet the conditions of friction imposed by plowing at the higher speeds. Similar results were obtained by Jones at the Missouri station (11). Further experiments by Keen and Haines at the Rothamsted Experimental Station (7) showed that, although the power requirement of plowing increased with the speed, the percentage increase was relatively so slight that considerable saving resulted, thus indicating the different conditions which may be imposed by the varying frictional properties of soils.

Further studies by Collins (12) showed that the type of plow bottom did not materially influence the draft, and that an increase in speed produced about the same increase in draft with any type of plow bottom in a particular soil. The increase in draft owing to increased speed was found to be confined to that part of the total which was required for turning and pulverizing, and varied with the speed from less than one-third to about one-half the total draft of the plow within a speed range of from 2 to 4 miles per hour. Friction between soil and plow seemed therefore to cause the increased draft with increased speed. Under some plowing conditions a sharp cutting edge was of little importance and under certain conditions high speeds caused failure to scour. Here friction and adhesion were apparently the active retarding agents. Davies of the Rothamsted Experimental Station (8)

found, however, that a greater proportion of the net draft in plowing was used in overcoming the resistance of the soil than in turning the furrow, thus again showing the possible variation in the engineering properties of soils.

The results of a large number of plow draft tests conducted by Sjogren at the Nebraska station (13), at different depths and speeds, varied widely in the case of speed draft tests, but were fairly constant for the depth draft tests. An increase in plowing depth of from 5 to 10 inches resulted in an increase in draft of 27 per cent. Other tests by Sjogren (14) with multiple bottom plows showed that there was improper scouring in wet gumbo soils, thus indicating the influence of moisture content in enhancing the adhesive and frictional properties. The draft showed no regular tendency under these conditions except to increase with the speed. In dry sandy loam the draft of a 2-bottom plow decreased as the speed increased up to 2.25 miles per hour and then increased. The results obtained with a 3-bottom plow were the reverse of those obtained with a 2-bottom plow in the same soil. The draft of a 2-bottom plow in moist clay loam was less at a speed of 4.66 miles per hour than at 2.97 miles per hour. The draft of a 5-bottom plow increased as the depth of plowing increased from 4.5 to 7 inches and then decreased up to an 8.5-inch depth. Ocock at the Illinois station (9) found an increased draft with increasing depth in all cases but a decreased draft per square inch of cross section of furrow with increasing depth. A 14-inch plow showed the lowest average draft per square inch of cross section, a 16-inch plow the highest, and an 18-inch plow a draft intermediate between the other two.

Davies at the Rothamsted Experimental Station (8) found a linear relation between draft and depth of furrow, except when the previous crop was a root crop, resulting in a decrease in draft at depths greater than 6 to 8 inches. A linear relation was also established between draft and width of furrow, increasing in some cases and decreasing in others. The double plow was found to be a more efficient implement in this respect than the single plow with similar fittings and moldboard.

These typical plowing results seem to indicate that the engineering properties of soils exert a definite influence on plowing, regardless of the construction, weight, or speed of operation of the plows used, and this influence

appears to vary mainly as the soil properties vary, with only minor regard to changes in the same type of plow.

CULTIVATION

The engineering properties of soils have also been found to be of considerable importance in cultivation or surface tillage. The draft of such tools is heavy, and efforts to reduce it are being constantly made. The disk harrow is a typical cultivating tool and is one having the heaviest draft.

Disking.—Tests of the draft of disk harrows at the California station (15) by Hoffman and Stirniman showed that at speeds ranging from 0.5 to 6.1 miles per hour, there was no increase in draft with an increase in speed, and in some cases there was a slight but definite decrease. Friction apparently was a minor factor in the draft in these tests. With a set of angle of gangs of 18° , cutaway disks pulled 15.5 per cent harder than full disks and the draft apparently increased as the angle at which the gangs were set increased from 3 to 23° . Here undoubtedly the factor of increased friction between metal and soil entered in sufficiently to profoundly influence the results.

Both Collins (16) and Stirniman (17), in work at the Iowa station, showed that the full disk harrow required less draft per foot of width than did the spader or cutaway disk when doing the same quality of work on similar soils. Collins found that the cutaway disk penetrated more deeply than the full disk, causing an increase of from 10 to 20 per cent in the draft according to the soil conditions. Stirniman showed that the cutaway disk had a greater draft even at smaller angles of inclination than the full disks under similar conditions, thus emphasizing the variable resistance of soil frictional and shearing properties to cultivating tools of different shapes as influenced by the depth of penetration and area of contact.

Tests by Sjogren at the Nebraska station (18) showed that the increase in draft due to fully angling the sections of a disk harrow was about 175 per cent of the draft at no angle. The draft of the disk when weighted with 180 pounds was 60 per cent greater than when no weight was added, again bringing out particularly the influence of friction as well as that of the other resistive properties of soils on draft. Jones at the Missouri station (19) showed the marked influence of previous plowing of soil on the draft of a

disk harrow, which would logically be attributed to a modification of the cohesive power of the soil.

FACTORS INFLUENCING THE ENGINEERING PROPERTIES OF SOIL

There appear to be certain special characteristics of soils which can uniformly account for the nature and intensity of their engineering properties, especially as they influence the design of tillage implements. Evidence has been obtained which points to the possible bearing which the colloidal phenomena and moisture content of soil may have on its engineering properties.

Colloidal phenomena.—Moore et al. of the Bureau of Soils of this department (20) showed the existence of so-called ultraclay in soils, which gives every evidence of being a true colloid. When moist it is very plastic and sticky, and when dry it is as much as 10 per cent a stronger binding agent than Portland cement. Ultraclay is therefore considered to be the principal binding material of soil, giving it plasticity, cohesiveness, or hardness according to its moisture content.

Middleton of the Bureau of Soils of this department (21) found further that the factors influencing the binding power of soil colloids are the amount, kind, and dispersion of the colloidal material present in soils, the moisture content, and the size and grading of the noncolloidal material present. Studies by Davis of the bureau (22) showed that the effect of adding small quantities of soluble salts on the physical properties and the structure of soils was most pronounced in soils containing a large percentage of fine particles. The conclusion was drawn that colloid-like clay particles are most affected and in turn most affect the structure and strength of soil. It is interesting to note in this connection that Keen and Haines of the Rothamsted Experimental Station (7) found that variations in the draft of plows could be closely correlated with the clay content of the soil.

The resistance of hardpan in soils to the stresses introduced by tillage operations appears to represent the extreme case of soil cohesion. The relation of the occurrence of these formations in soil to colloidal phenomena and reaction seems quite probable in view of the results obtained in studies by Morison of the Rothamsted Experimental Station (23), and by Skeen of the University of Pennsylvania (24).

Jensen of this department (25) showed that the percentage of iron and alu-

minum in colloidal suspensions from soil is directly correlated with the readiness with which the soil forms a plow-sole.

Moisture.—Moisture appears to have a marked influence on the cohesive, adhesive, and other engineering properties of soils not only directly but also indirectly through its influence on soil colloids. Studies by Bouyoucos at the Michigan station (26) on the influence of water on soil granulation, showed that water pushes the soil particles apart and thus produces a crumbling of dense masses of clods into a loose, granular structure. This is a result of swelling of the colloids and of a diminishing of the cohesive force of the particles as the water comes between them. Goldbeck and Jackson of the Bureau of Public Roads of this department (27) found further that, in general, moisture equivalents increase with the percentage of very fine silt and clay in soil, and that there is a fairly definite relation between the moisture equivalent and the mechanical analysis. The bearing power of most soils is not appreciably reduced by the addition of moisture up to the moisture equivalent, but saturation beyond this point causes a rapid reduction in bearing power. Thus an almost direct relation between colloidal phenomena and bearing power in soils through the medium of moisture equivalent is indicated.

External treatments.—Since moisture and colloidal phenomena appear to markedly influence the engineering properties of soils, it seems likely that certain external treatments which may influence the colloidal phenomena and the relation of moisture thereto may also indirectly influence these properties.

Russell and Keen at the Rothamsted Experimental Station (28) showed, for instance, that chalking of certain soils not only permitted an increase in the speed of plowing but considerably reduced the draft without change in the implemental factors. Studies by Allison at the New Jersey stations (29) showed that in a clay soil the effect of liming was promptly noticeable through a decrease in the modulus of rupture in cross bending. On the other hand, liming caused an increase in the modulus of rupture of a loam soil. These and similar results were taken to indicate that the action of lime on the strength properties of soils is distinctly differential, depending apparently upon the nature and type of the soil.

Beeson of the Oklahoma station (30) showed that lime and manure greatly decreased the resistance of hardpan formations in soils to penetration.

However, Jensen of this department (25) found that lime appreciably decreased the percentage of inorganic colloidal suspension in soil when no organic matter was added. When organic matter was added the flocculating effect of lime was appreciably diminished, especially in clay soil. Powdered sulphur and gypsum markedly decreased the content of inorganic colloidal suspension in soil, and organic matter had no appreciable effect in counteracting the flocculating influence of these two materials. Sodium nitrate, on the other hand, markedly increased the amount of colloidal suspension in soils, but organic matter appreciably decreased the deflocculating influence of this fertilizer material.

These results indicate the possible influence of external treatments on the properties of soils which influence tillage operations. They are significant, however, in that they seem to show that although organic manures, lime, and other amendments and fertilizers may reduce the influence of these properties in some soils if properly applied, they can not be used indiscriminately in the expectation that results favorable to tillage will always be obtained.

This is partially explained by studies conducted at the University of Leeds by Comber (31) on the flocculation of neutral and alkaline suspensions of clay, silt, and soil by lime. These showed that silt, when suspended in water, was most easily flocculated by lime if the suspension was neutral. The addition of alkali rendered flocculation more difficult. Soil clay, on the other hand, was flocculated by lime in alkaline suspensions more readily than in neutral suspensions, resembling silicic acid and other emulsoid colloids in this respect. Further studies showed that clay, as an emulsoid, protects the larger soil particles which by themselves are suspensoids. Clay therefore ultimately imposes its emulsoid nature on the whole soil in normal cases. Fine silt soils are therefore not flocculated by lime owing to the inability of the relatively small amount of emulsoid clay to protect the large suspensoid surface exposed by the fine silt.

RELATION OF SOIL PROPERTIES TO THE DESIGN OF TILLAGE IMPLEMENTS

The engineering properties of soils are apparently definite factors, which are more or less susceptible of measurement, and which are largely governed by and vary with the colloidal phenomena and moisture content of soils. They indicate lines along which studies for

the development of tillage implements might profitably proceed. Some work has been done in this connection, with special reference to soil friction.

Friction.—Friction, resulting largely from adhesion and cohesion and strongly influenced by moisture and colloidal phenomena, seems to be the most important individual power-consuming factor of tillage. From the results of experiments made at Rothamsted, Crowther and Haines (32) estimated that approximately one-third of the total work done in plowing is expended in overcoming the adhesive and frictional forces between the moldboard surface and the soil. This frictional force was reduced by an electrical method which depends upon the phenomenon of electroendosmose exhibited by moist soil. It was found that by virtue of the negative charge of the soil colloids, water will move through moist soil toward the negative electrodes under the action of an electric current. When a current was passed through the soil, having the moldboard of the plow as the negative electrode, the film of water formed at the soil-metal surface apparently acted as a lubricant and reduced the plowing draft. These results indicate the prominent part which moisture may play in that part of the draft of tillage due to friction.

Further studies by Haines (33) on surface friction between metal and a light sandy soil and a heavy loam, as they were gradually dried, showed that both soils gave a practically constant friction for a range of moisture content from 0 to 12 per cent. At this point the soils began to wet the metal and an increase in friction resulted. This increase reached a maximum at about 17 per cent moisture content in the light sandy soil. Beyond that point the metal surface was wetted so freely as to be apparently lubricated by the water film, and the friction decreased. This continued until the soil was too fluid to bear the weight of the metal slider.

The heavy loam soil, on the other hand, showed two frictional maxima instead of only one. These two maxima corresponded to the two different ways in which the soil wet the metal surface, namely, wetting without sticking and wetting with sticking. In the first case the water in the larger capillaries of the soil wet the metal surface, but the soil itself remained firm and coherent and the metal slid without being contaminated by the soil to an appreciable extent. The pores of this soil were just full of water at about 19 per cent moisture content, so that

the wetting began a little before this stage was reached and extended considerably beyond it. The second increase in the friction began as the soil began to stick to the metal. This corresponded to a definite stage of water saturation of the clay in the soil, and true surface friction ceased at this point, since the slippage took place within the top layers of the soil itself. The governing factor was then the plasticity. This seems to indicate that the soil moisture most active in connection with the frictional phenomena involved in tillage is the hygroscopic moisture.

White, at the New York Cornell station (34), established the fact that soil particles follow very definite paths when passing over the surface of a moldboard. With this in view and considering friction between soil and metal surfaces as the biggest consumer of power in tillage, Nichols of the Alabama station (35) undertook a laboratory study of the sliding of metal over soil to elucidate the principles of friction between the soil and the metal surface as they relate specifically to the power requirement of tillage. It was found possible to lay down certain fundamental laws for sliding friction between a metal surface and synthetic sand-clay mixtures varying by degrees of 25 per cent from 100 per cent sand to 100 per cent clay.

These laws, though holding only within the limits tested, were nevertheless directly applicable in explaining certain phenomena relating to the draft of plows and other tillage tools established in draft tests by others. It was found that in a dry soil, when the value of the coefficient of wetting of the soil solution was negative, i. e., when the metal surface was not wetted, and when the bearing power of the soil was less than the pressure, the sliding friction varied with the speed and with the smoothness and composition of the metal surface, and was proportional to the pressure per unit area. When the bearing power of the soil was greater than the pressure per unit area and the value of the coefficient of wetting of the soil solution was still negative, the friction was proportional to the pressure and depended upon the smoothness and composition of the metal surface. It was independent of the area of contact and the speed of sliding. When there was enough moisture present in the soil to cause it to adhere to the sliding metal surface but not enough to leave any of it on the metal surface, the friction varied with the speed, the area of contact, the pressure per unit

area, the amount of colloidal matter present, the amount of water present, the temperature and viscosity of the soil solution, and the nature and composition of the metal surface. When there was enough moisture present in the soil to give an apparent lubricating effect, the friction varied with the pressure per unit area, the speed of sliding, the amount and viscosity of the soil solution, and the nature and composition of the metal surface.

These results indicate that frictional resistance, the individual factor which probably most affects the draft and quality of tillage, is therefore dynamic and constantly varying. It is affected primarily by the moisture content and size of particles of the soil, and therefore, at the stage where plowing becomes most difficult, its magnitude is determined largely by the colloidal phenomena of the soil.

The importance of these factors in the practical design of tillage tools is obvious. For instance, in the normally dry soil first noted, the plow shape which will give the lowest speed of soil over the metal surface and the lowest pressure per unit area of contact will give the least frictional resistance. Soils of this nature are, however, usually plowed with a steep moldboard, which is directly opposed to the indications of the laws of friction as applied to proper practice. The second condition noted would also seem to require gentler moldboard slopes for minimum frictional resistance.

These results would therefore seem to have considerable bearing on those obtained in the experiments enumerated above on the effect of speed on plowing draft. Obviously in normally dry soil the draft would increase with the speed. However, when the bearing power of the soil is greater than the pressure per unit area, speed would have little influence on the draft of normally dry soil and would again become a factor of importance only when the soil became wet enough to become sticky.

The most significant feature of these results, however, especially from the standpoint of further study, seems to be that the frictional resistance depends upon the nature and composition of the metal surface throughout the entire range of soil types and moisture contents studied. The practical solution of the problem involved in the sticking of soil to plow metal and in the frictional resistance to plowing seems to be closely allied with the physical properties of the metal surface. It was shown that the factors favoring

such sticking action are more active the greater the tendency of the soil solution to wet and spread on the metal surface in soils which are still not too wet to plow. This tendency is designated and measured by the so-called coefficient of spreading of the soil solution. Attempts to modify the soil solution by external treatments, so as to reduce its tendency to spread on and wet the surfaces of available plow metals, may offer possibilities. The more practical and immediate solution of the problem would, however, seem to lie in the development of plow metal surfaces having such a molecular composition as to offer a maximum resistance to wetting by the soil solution. That this is not impracticable is indicated by the existence of noncorrosive steels which are used in cutlery, hand tools, and certain machine parts.

Apparently such a development of the composition of plow metal surfaces should also have an influence on the tendency of such surfaces to wear in service. It is interesting to note in this connection that the wear of the metal surfaces of tillage tools does not always conform to the accepted principles of the wear of metals. For instance, Hoffman of the California station (36) found, in wearing tests of manganese steel, soft center steel, and chilled cast-iron plowshares in soils, that the least wear was shown by the chilled cast iron and the most by the manganese steel. In other words, the hard and extremely tough manganese steel showed greater wear by frictional contact with soil than the hard but extremely brittle chilled cast iron. It seems quite conceivable that the molecular composition of the chilled cast iron was of such a nature as to practically prevent the solution of the particular soils plowed from spreading on and wetting its surface, thus reducing frictional wear to a minimum. On the other hand, the molecular composition of the manganese steel would seem to have been of such a nature as to invite the spreading on and wetting of its surface by the particular soil solution encountered, thus permitting frictional wear to reach a possible maximum.

CONCLUSIONS

The importance of the engineering properties of soil, as indicated by its resistance to various kinds of stress, on the development of machinery capable of producing desired tillage results with a minimum utilization of power seems evident. Apparently the more active of these properties, from the standpoint of tillage, are in turn gov-

erned largely by the moisture content and the colloidal phenomena of soil.

Fertilizer and cropping treatments to increase the productiveness of soils also seem to exert a marked influence on these engineering properties, when properly applied, and may therefore facilitate the development of tillage machines capable of producing desired tillage results.

A consideration of these important soil characteristics in connection with certain of the fundamental laws of physics seems especially to throw considerable light on the design of tillage implements capable of producing desired tillage results with a minimum utilization of power. For example, the laws of physics governing the friction between soil and metal surfaces appear important in this connection, especially when the possibility of wide modification and variation of the physical properties of the metal surfaces is considered.

The importance of first recognizing and taking proper advantage of natural or artificial influences favorable to tillage seems evident. The opportunity for further development of research in the mechanics of tillage appears to lie largely in a closer cooperation by the agricultural engineer with the agronomist, soils physicist, and the metallurgist.

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(18) Nebr. Sta. Rpt. 1921, pp. 23, 24.

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(34) A study of the plow bottom and its action on the furrow slice. E. A. White. Jour. Agr. Research [U. S.], 12 (1918), No. 4, pp. 149-182.

(35) The sliding of metal over soil. M. L. Nichols. Agr. Engin., 6 (1925), No. 4, pp. 80-84.

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PUBLICATIONS OF THE STATIONS (1924-25)

The following is a list of publications received by the office during the year ended June 30, 1925. Only publications of the regular station series are listed. The large and very important part of the station output published through other channels is not included. (See p. 13.)

AGRICULTURAL CHEMISTRY—AGROTECHNY

Studies with phytosterols: I, The phytosterols of the endosperm of corn. R. J. Anderson. II, The phytosterols of wheat endosperm. R. J. Anderson and F. P. Nabenhauer. III, The separation of unsaturated from saturated sterols. R. J. Anderson and F. P. Nabenhauer. IV, Reduction of sitosterol preparation of dihydrositosterol or sitostanol. R. J. Anderson and F. P. Nabenhauer. V, Sitosterol. R. J. Anderson and F. P. Nabenhauer. (N. Y. State Sta. Tech. Bul. 108, pp. 40, fig. 1. Sept., 1924.)

Some chemical characteristics of soft corn. A. Bushey. (S. Dak. Sta. Bul. 210, pp. 713-718, figs. 3. June, 1924.)

Some chemical aspects of sweet corn drying. C. O. Appleman. (Md. Sta. Bul. 267, pp. 287-298 June, 1924.)

Cornstalk syrup investigations. J. J. Willaman, G. O. Burr, and F. R. Davison. (Minn. Sta. Bul. 207, pp. 58, figs. 22. Mar., 1924.)

The Hawaiian tree fern as a commercial source of starch. J. C. Ripperton. (Hawaii Sta. Bul. 53, pp. 16, pls. 7, figs. 2. July, 1924.)

Olive pickling in Mediterranean countries. W. V. Cruess. (Calif. Sta. Circ. 278, pp. 33, figs. 19. Sept., 1924.)

The preparation and refining of olive oil in southern Europe. W. V. Cruess. (Calif. Sta. Circ. 279, pp. 43, figs. 24. Oct., 1924.)

Chemical studies of the combined lead arsenate and lime-sulfur spray. R. W. Thatcher and L. R. Streeter. (N. Y. State Sta. Bul. 521, pp. 20. Aug., 1924.)

METEOROLOGY

Meteorological observations at the Massachusetts Agricultural Experiment Station. J. E. Ostrander et al. (Mass. Sta. Met. Buls. 426-437, pp. 4 each. June, 1924-May, 1925.)

Climatological data for Wyoming. F. E. Hepner. (Wyo. sta. Bul. 139, pp. 63-160, pls. 2, figs. 11. June, 1924.)

SOILS—FERTILIZERS

Alkali soils in Montana. E. Burke and R. M. Pinckney. (Mont. Sta. Bul. 172, pp. 20, fig. 1. Jan., 1925.)

A progress report of alkali land reclamation investigations in eastern Oregon. W. W. Johnston and W. L. Powers. (Oreg. Sta. Bul. 210, pp. 27, figs. 13. Oct., 1924.)

Treatment of black alkali with gypsum. C. N. Catlin and A. E. Vinson. (Ariz. Sta. Bul. 102, pp. 291-337, pl. 1, figs. 21. Mar., 1925.)

Results of soil fertility investigations, 1913-1922 [North Vernon Experiment Field]. C. Juengst. (Ind. Sta. [Leaflet], pp. 4. 1923.)

Results of soil fertility investigations, 1906-1922 [Scottsburg Experiment Field]. A. G. Mace. (Ind. Sta. [Leaflet], pp. 4. 1923.)

Results of soil fertility investigations, 1917-1922 [Francisco Experiment Field]. A. T. Wiancko and W. G. Volkmann. (Ind. Sta. [Leaflet], pp. 4. 1924.)

Results of soil fertility investigations, 1913-1922 [Worthington Experiment Field]. A. T. Wiancko and F. Negele. (Ind. Sta. [Leaflet], pp. 4. 1924.)

The maintenance of soil fertility.—Thirty years' work with manure and fertilizers. C. E. Thorne. (Ohio Sta. Bul. 381, pp. 243-354, figs. 10. June, 1924.)

The results of some fertility experiments on Oklahoma soils. H. F. Murphy. (Okla. Sta. Bul. 155, pp. 34, fig. 1.)

The fertility of Washington soils. F. J. Sievers and H. F. Holtz. (Wash. Col. Sta. Bul. 189, pp. 45, figs. 14. Dec., 1924.)

Maintaining the productivity of irrigated land. D. W. Pittman. (Utah Sta. Bul. 188, pp. 24, figs. 8. June, 1924.)

Replaceable bases in soils. W. P. Kelley and S. M. Brown. (Calif. Sta. Tech. Paper 15, pp. 39. Sept., 1924.)

The toxicity, movement, and accumulation of nitrates and other salts occurring in arid soils. C. E. Craig. (N. Mex. Sta. Bul. 142, pp. 65. Apr. 1924.)

The availability of phosphorus in calcareous and noncalcareous soils. J. W. Ames and C. J. Schollenberger. (Ohio Sta. Bul. 380, pp. 213-242. June, 1924.)

Soil potassium as affected by fertilizer treatment and cropping. J. W. Ames and R. H. Simon. (Ohio Sta. Bul. 379, pp. 183-212, fig. 1. June, 1924.)

Effect of cropping upon the active potash of the soil. G. S. Fraps. (Tex. Sta. Bul. 325, pp. 18, fig. 1. Sept., 1924.)

The moisture equivalent as influenced by the amount of soil used in its determination. F. J. Veihmeyer, O. W. Israelson, and J. P. Conrad. (Calif. Sta. Tech. Paper 16, pp. 61, pls. 2, figs. 9. Sept., 1924.)

A study of the biological activities in certain acid soils. W. V. Halverson. (Oreg. Sta. Bul. 211, pp. 26, figs. 5. Feb., 1925.)

Experiments with subsoiling, deep tilling, and subsoil dynamiting. R. S. Smith. (Ill. Sta. Bul. 258, pp. 153-170, figs. 6. Feb., 1925.)

The principles of summer fallow tillage. M. A. McCall and H. M. Wanzer. (Wash. Col. Sta. Bul. 183, pp. 77, figs. 5. Oct., 1924.)

Saving soil by use of mangum terraces. E. W. Lehmann and F. P. Hanson. (Ill. Sta. Circ. 290, pp. 19, figs. 18. July, 1924.)

Hancock County Soils. R. S. Smith, E. E. De Turk, F. C. Bauer, and L. H. Smith. (Ill. Sta. Soil Rpt. 27, pp. 62, pls. 2, figs. 9. May, 1924.)

Mason County Soils. R. S. Smith, E. E. De Turk, F. C. Bauer, and L. H. Smith. (Ill. Sta. Soil Rpt. 28, pp. 62, pls. 2, figs. 9. June, 1924.)

Soil survey of Iowa.—Mills County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 33, pp. 63, pl. 1, figs. 13. Mar., 1924.)

Soil Survey of Iowa.—Boone County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 34, pp. 70, pl. 1, figs. 13. Apr., 1924.)

Soil survey of Iowa.—Dubuque County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 35, pp. 72, pls. 2, figs. 14. Sept., 1924.)

The soils of Rutherford County. C. A. Mooers and H. H. Coryell. (Tenn. Sta. Bul. 130, pp. 27, figs. 6, map 1. June, 1924.)

The soils of Brazos, Camp, Ellis, and Washington Counties. G. S. Fraps. (Tex. Sta. Bul. 316, pp. 88, figs. 6. Feb., 1924.)

The chemical composition of the soils of the Bernardsville area in New Jersey. A. W. Blair and A. L. Prince. (N. J. Stas. Bul. 406, pp. 16, figs. 2. Nov., 1924.)

The chemical composition of the soils of the Chatsworth area in New Jersey. A. W. Blair and A. L. Prince. (N. J. Stas. Bul. 414, pp. 15, figs. 2. Apr., 1925.)

Chemical analyses and fertility of West Virginia Soils. O. C. Bryan and E. P. Deatrick. (W. Va. Sta. Bul. 184, pp. 27, fig. 1. July, 1924.)

The results of fertilizer experiments, 1922-1923. M. Nelson and W. H. Sachs. (Ark. Sta. Bul. 192, pp. 12, figs. 2. June, 1924.)

Fifteen years of field experiments with manure, fertilizers, and lime on Sassafras silt loam soil. G. L. Schuster. (Del. Sta. Bul. 137, pp. 43, fig. 1. June, 1924.)

Economic returns from fifteen years results with manure, fertilizers, and lime on Sassafras silt loam soil. G. L. Schuster. (Del. Sta. Bul. 138, pp. 47, figs. 21. Aug., 1924.)

Fertilizers, what they are and how to use them. M. M. McCool and C. E. Millar. (Mich. Sta. Spec. Bul. 133, pp. 26, figs. 24. June, 1924.)

The use of fertilizers on Iowa soils. W. H. Stevenson and P. E. Brown. (Iowa Sta. Circ. 97, pp. 16, fig. 1. Mar., 1925.)

What is the value of a ton of stable manure? A. G. McCall and T. H. White. (Md. Sta. Bul. 266, pp. 259-286, figs. 4. May, 1924.)

Lime and its relation to crop production in Virginia. T. B. Hutcheson and T. K. Wolfe. (Va. Sta. Bul. 237, pp. 20, figs. 5. Nov., 1924.)

Gypsum and sulfur as fertilizers for legumes. J. L. St. John and J. R. Noller. (Wash. Col. Sta. Pop. Bul. 128, pp. 11. June, 1924.)

Changes in the composition and cost of fertilizers in New York from 1914 to 1924. L. L. Van Slyke. (N. Y. State Sta. Bul. 525, pp. 19. Dec., 1924.)

BOTANY—PLANT NUTRITION

Studies on the Coccoaceae.—I, Previous taxonomic studies concerning the genera of the Coccoaceae. G. J. Hacker. (N. Y. State Sta. Tech. Bul. 99, pp. 44. June, 1924.)

Studies on the Coccoaceae.—II, A study of the general characters of the Micrococcidae. G. J. Hacker. (N. Y. State Sta. Tech. Bul. 100, pp. 83, fig. 1. June, 1924.)

Studies on the Coccoaceae.—III, The nitrogen metabolism of the Micrococcidae. G. J. Hacker. (N. Y. State Sta. Tech. Bul. 101, pp. 47. June, 1924.)

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Thirty-sixth annual report of the agricultural experiment station of the Michigan Agricultural College for the year ending June 30, 1923. R. S. Shaw et al. pp. 504, figs. 108.

Thirty-first annual report of the [Minnesota] Agricultural Experiment Station, 1923. W. C. Coffey. pp. 31.

[Minnesota] Agricultural Experiment Station, thirty-second annual report.—Part I, Publications, list of projects, financial statement, and staff members, July 1, 1923, to June 30, 1924. W. C. Coffey. pp. 38.

Minnesota Agricultural Experiment Station, thirty-second annual report.—Part II, Popular discussions of some of the experimental work in animal husbandry, dairy husbandry, veterinary medicine, poultry husbandry, and bee culture, 1924, pp. 40, figs. 10.

Thirty-sixth annual report [Mississippi Agricultural Experiment Station] for the fiscal year ending June 30, 1923. J. R. Ricks et al. pp. 63. June, 1:23.

New knowledge.—One year's work, agricultural experiment station (report of the director, July 1, 1923, to June 30, 1924). F. B. Mumford. (Mo. Sta. Bul. 228, pp. 86, figs. 14. Jan., 1925.)

Agricultural service from the Montana Experiment Station. Thirtieth annual report, July 1, 1922, to June 30, 1923. F. B. Linfield et al. pp. 71, figs. 32.

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Annual report of the board of control [Nevada Agricultural Experiment Station] for the fiscal year ending June 30, 1923. S. B. Doten et al. pp. 16.

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Progress of agricultural experiments—1924. A report of the director of the New Hampshire Agricultural Experiment Station for the year 1924, including a financial statement for the fiscal year ending June 30, 1924. (N. H. Sta. Bul. 216, pp. 35. Feb., 1925.)

Forty-fourth annual report of the New Jersey State Agricultural Experiment Station and the thirty-sixth annual report of the New Jersey Agricultural College Experiment Station for the year ending June 30, 1923. J. G. Lipman et al. pp. 414, pls. 17, figs. 10.

Thirteenth annual report agricultural experiment station of the New Mexico College of Agriculture and Mechanic Arts, 1923-1924. F. Garcia. pp. 55, figs. 2.

Thirty-seventh annual report of the dean [New York State College of Agriculture and Agricultural Experiment Stations], 1924. A. R. Mann. pp. 89.

Forty-third annual report [of the New York State Station] for the fiscal year ended June 30, 1924. R. W. Thatcher. pp. 56.

Forty-sixth annual report of the North Carolina Agricultural Experiment Station for the fiscal year ended June 30, 1923. Statistical report year ending December 1, 1923. B. W. Kilgore, F. E. Miller, F. H. Jeter, et al. pp. 103, pl. 1, figs. 17.

Experiment station progress. Report of director [North Dakota Agricultural Experiment Station], July, 1921, to June 30, 1923. P. F. Trowbridge et al. pp. 100, figs. 25.

Forty-third annual report for 1923-24. C. G. Williams. (Ohio Sta. Bul. 382, pp. 68, figs. 16 June, 1924.)

New information for Oklahoma farmers. A biennial report of the Oklahoma Agricultural Experiment Station for 1922-1924. C. T. Dowell. pp. 36, figs. 3.

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Report of the Porto Rico Agricultural Experiment Station, 1923. D. W. May et al. pp. 18, pls. 4.

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Thirty-seventh annual report of the South Carolina Experiment Station of Clemson Agricultural College for the year ended June 30, 1924. H. W. Barre. pp. 95, figs. 30.

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Thirty-fifth annual report of the Texas Agricultural Experiment station, 1922. B. Youngblood. pp. 15.

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Report of the Virgin Islands Agricultural Experiment Station, 1923. J. B. Thompson et al. pp. 13, pls. 3, fig. 1.

Thirty-fourth annual report for the fiscal year ended June 30, 1924. E. C. Johnson. (Wash. Col. Sta. Bul. 187, pp. 111. Dec., 1924.)

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Fourth annual report, 1923. S. H. Starr. (Ga. Coastal Plain Sta. Bul. 4, pp. 44, figs. 17. June, 1924.)

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Report from Holly Springs Branch Experiment Station for 1924. C. T. Ames. (Miss. Sta. Bul. 223, pp. 25, fig. 1. Dec., 1924.)

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Dickinson substation report for 1922 and 1923. L. Moomaw. (N. Dak. Sta. Bul. 189, pp. 46, figs. 8. Feb., 1925.)

Twenty-third report of the State Entomologist of Connecticut, 1923. W. E. Britton et al. (Conn. State Sta. Bul. 256, pp. 221-316, pls. 16, figs. 8. Feb., 1924.)

Twenty-fourth report of the State Entomologist of Connecticut, 1924. W. E. Britton et al. (Conn. State Sta. Bul. 265, pp. 221-344, pls. 20, figs. 9. Mar., 1925)

Montana insect pests for 1923 and 1924, being the twentieth report of the State Entomologist of Montana. R. A. Cooley. (Mont. Sta. Bul. 170, pp. 30, figs. 6. Jan., 1925.)

Second report of the Tree Protection Examining Board. W. E. Britton, C. P. Clinton, and W. O. Filley. (Conn. State Sta. Bul. 263, pp. 137-192, pls. 8. Dec., 1924.)

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Agricultural experiment station work (tentative plans). H. G. Knight. (*W. Va. Sta. Bul.* 193, pp. 32. Dec., 1924.)

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Reymann Memorial Farms. H. G. Knight. (*W. Va. Sta. Bul.* 194, pp. 20, figs. 19. Feb., 1925.)

Some results from agricultural stations over the State. W. L. Quayle. (*Wyo. Sta. State Farms Bul.* 4, pp. 14, figs. 3. Aug., 1923.)

The service of the State experiment farms. W. L. Quayle. (*Wyo. Sta. State Farms Bul.* 5, pp. 68, figs. 33. Jan., 1925.)

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Quarterly Bulletin, Michigan Agricultural Experiment Station.—Vol. 7 (1924), No. 1, pp. 38, figs. 12; No. 2, pp. 41-71, figs. 6; (1925), No. 3, pp. 73-118, figs. 12; No. 4, pp. 121-168, figs. 12.

Farmers' Market Bulletin, North Carolina Agricultural Experiment Station.—Vol. 11 (1924), No. 69, pp. 11; No. 70, pp. 16, figs. 3; No. 72, pp. 8.

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Bimonthly Bulletin, Western Washington Experiment Station, Puyallup, Wash.—Vol. 12 (1924), No. 2, pp. 25-51, figs. 9; No. 3, pp. 53-76, figs. 8; No. 4, pp. 77-96, figs. 3; (1925), No. 5, pp. 97-124, figs. 7.

REGULATORY PUBLICATIONS, FERTILIZERS

Fertilizer report for 1924. E. M. Bailey. (*Conn. Sta. Bul.* 261, pp. 100. Nov. 1924.)

Commercial fertilizers. E. G. Proulx et al. (*Ind. Sta. Bul.* 280, pp. 59, fig. 1. May, 1924.)

Analyses of commercial fertilizers. H. E. Curtis, H. R. Allen, and L. Gault. (*Ky. Sta. Bul.* 251, pp. 369-485. Dec., 1923.)

Commercial fertilizers, 1924. J. M. Bartlett. (*Me. Sta. Off. Insp.* 113, pp. 37-68. Oct., 1924.)

Inspection of commercial fertilizers. H. D. Haskins, L. S. Walker, and G. B. Dalrymple. (*Mass. Sta. Control Ser.* Bul. 29, pp. 32. Nov., 1924.)

Testing fertilizers for Missouri farmers, 1924. L. D. Haigh. (*Mo. Sta. Bul.* 230, pp. 57, fig. 1. Feb., 1925.)

Inspection of commercial fertilizers for 1924. H. R. Kraybill, T. O. Smith, and S. R. Shimer. (*N. H. Sta. Bul.* 214, pp. 19. Nov., 1924.)

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Commercial fertilizers in 1923-1924. G. S. Fraps and S. E. Asbury. (*Tex. Sta. Bul.* 322, pp. 61. Sept., 1924.)

Commercial fertilizers. J. L. Hills, C. H. Jones, and G. F. Anderson. (*Vt. Sta. Bul.* 240, pp. 24. Aug. 1924.)

REGULATORY PUBLICATIONS, FEEDING STUFFS

Report on inspection of commercial feeding stuffs, 1923. E. M. Bailey. (*Conn. Sta. Bul.* 257, pp. 317-359. Apr., 1924.)

Commercial feeding stuffs in Kentucky in 1924. J. D. Turner, H. D. Spears, and W. G. Terrell. (*Ky. Sta. Bul.* 257, pp. 3. Feb., 1925.)

Commercial feeding stuffs, 1923, 1924. J. M. Bartlett. (*Me. Sta. Off. Insp.* 112, pp. 17-36. Aug., 1924.)

Inspection of commercial feedstuffs. P. H. Smith and F. J. Kokoski. (*Mass. Sta. Control Ser.* Bul. 28, pp. 35. Nov., 1924.)

Inspection of commercial feeding stuffs, 1924. H. R. Kraybill, T. O. Smith, and J. T. Sullivan. (*N. H. Sta. Bul.* 213, pp. 63. Aug., 1924.)

Analyses of commercial feeding stuffs and registrations for 1924. C. S. Cathcart et al. (*N. J. Stas. Bul.* 399, pp. 76, fig. 1. July, 1924.)

Inspection of feeds. J. B. Smith and W. L. Adams. (*R. I. Sta. Ann. Feed Circ.*, pp. 12. Apr., 1925.)

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Commercial feeding stuffs. J. L. Hills, C. H. Jones, and G. E. Anderson. (*Vt. Sta. Bul.* 242, pp. 32. Oct., 1924.)

REGULATORY PUBLICATIONS, FOODS AND DRUGS

The twenty-eighth report on food products and the sixteenth report on drug products, 1923. E. M. Bailey. (*Conn. Sta. Bul.* 255, pp. 161-219. Feb., 1924.)

Foods and drugs. J. M. Bartlett. (*Me. Sta. Off. Insp.* 111, pp. 16. Apr., 1924.)

REGULATORY PUBLICATIONS, SEEDS

Inspection of agricultural seeds. E. G. Proulx et al. (*Ind. Sta. Bul.* 285, pp. 63, fig. 1. Jan., 1925.)

Seed analyses, 1921-1924. C. M. King. (*Iowa Sta. Bul.* 226, pp. 291-311. Feb., 1925.)

Ten years' grain and seed testing in Montana. Annual report of the Montana Grain Inspection Laboratory July 1, 1922, to June 30, 1923. C. McKee and W. O. Whitcomb. (*Mont. Sta. Bul.* 167, pp. 18, figs. 5. Oct., 1924.)

Results of seed tests for 1924 made for the State Department of Agriculture. M. G. Eastman. (*N. H. Sta. Bul.* 215, pp. 18. Dec., 1924.)

Results of seed and legume inoculant inspection for 1924. J. G. Fiske. (*N. J. Stas. Bul.* 412, pp. 72, fig. 1. Mar., 1925.)

Rules for seed testing. M. T. Munn. (*N. Y. State Sta. Circ.* 73, pp. 16. Feb., 1924.)

Agricultural seed inspection. A. S. Lutman. (*Vt. Sta. Bul.* 241, pp. 7. Oct., 1924.)

REGULATORY PUBLICATIONS, MISCELLANEOUS

Report on commercial insecticides and fungicides.—I, Text of the insecticide law of Connecticut and regulations for its enforcement. W. L. Slate, Jr., and T. Holt. II, Examination of insecticides and fungicides, etc. E. M. Bailey. (*Conn. Sta. Bul.* 258, pp. 361-377. June, 1924.)

Analyses of materials sold as insecticides and fungicides during 1924. C. S. Cathcart and R. L. Willis. (N. J. Sta. Bul. 407, pp. 16. Nov., 1924.)

Stallion enrollment.—XIII, Report of stallion enrollment work for the year 1924 with lists of stallions and jacks enrolled. (Ind. Sta. Circ. 120, pp. 48, fig. 1. Dec., 1924.)

Tenth annual report of the dairy department creamery license division for the year ending March 31, 1924. W. G. Goss. (Ind. Sta. Circ. 118, pp. 16, figs. 2.)

Inspection of lime products used in agriculture. H. D. Haskins, L. S. Waiker, and G. B. Dalrymple. (Mass. Sta. Control Ser. Bul. 30, pp. 6, fig. 1. Dec., 1924.)

PUBLICATION LISTS AND MISCELLANEOUS

Publications available for free distribution. (Idaho Sta. Circ. 37, pp. 4. Jan., 1925.)

Information regarding recent publications. (Kans. Sta. Circ. 111, pp. 4. Apr., 1925.)

Abstracts of papers not included in bulletins, finances, meteorology, index. (Me. Sta. Bul. 315, pp. 95-118 + XI. Dec., 1923.)

Bulletin summary. (Mass. Sta. Circ. 71, pp. 4. Feb., 1924.)

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INCOME, EXPENDITURES, AND OTHER STATISTICS

By J. I. SCHULTE

In the following tables will be found detailed data regarding personnel, publications, and mailing lists of the experiment stations; revenues and additions to equipment, 1925; a classified statement of expenditures from the Hatch and Adams funds; and a statement of disbursements from the United States Treasury under the Hatch and Adams Acts from their enactment to the end of the fiscal year, June 30, 1925.

TABLE 2.—*Personnel, publications, and mailing lists, 1925*

Station	Number on staff	Number of teach- ers on staff	Number on staff who assist in exten- sion work	Publications during fiscal year 1924-25		Number of names on mailing list
				Number	Pages	
Alabama (College)	32	14	3	12	60	950
Alabama (Tuskegee)	5	4				
Alaska	8			1	37	3,000
Arizona	24	20	1	14	357	6,850
Arkansas	29	23		7	172	4,000
California	150	87	84	60	1,861	13,896
Colorado	45	18	8	12	253	1,700
Connecticut (State)	32		1	14	592	9,373
Connecticut (Storrs)	17	8		12	440	9,000
Delaware	14	8	3	3	93	7,000
Florida	21	1	3	9	266	20,000
Georgia	9	1	1	25	83	9,784
Guam	4			2	32	
Hawaii	6		3	6	132	1,500
Idaho	35	19	9	8	198	17,610
Illinois	102	74	30	39	1,372	23,000
Indiana	77	19		33	890	36,760
Iowa	87	26		30	943	37,932
Kansas	82	44		15	572	12,500
Kentucky	58	27	7	7	276	13,500
Louisiana (Sugar)						
Louisiana (State)	22	3	10	2	105	6,500
Louisiana (North)						
Maine	14			11	284	20,100
Maryland	39	26	1	7	204	33,000
Massachusetts	50	16		23	230	10,000
Michigan	79	37	10	30	1,284	45,000
Minnesota	125	165		44	1,184	15,600
Mississippi	34	3		9	104	18,000
Missouri (College)	68	56		97	1,460	5,747
Missouri (Fruit)	4					
Montana	35	13	4	19	543	6,000
Nebraska	40	20		17	734	12,041
Nevada	9	1		4	77	7,000
New Hampshire	28	20	11	7	147	6,700
New Jersey (State)	67	41	5	96	1,830	16,300
New Jersey (College)	14					
New Mexico	18	16	2	83	257	9,000
New York (State)	50			27	814	22,800
New York (Cornell)	88	68	27	29	1,788	3,050
North Carolina (College)	45	10	9	6	355	13,876
North Dakota	51	10		12	600	12,000
Ohio	74	11	12	70	826	70,470
Oklahoma	27	29		9	159	17,000
Oregon	56	31		13	312	1,640
Pennsylvania	88	75		8	216	45,300
Pennsylvania (Nutrition)	8					
Porto Rico	9			1	18	3,000
Rhode Island	12			10	170	2,800
South Carolina	32	9	6	7	447	5,500
South Dakota	17	21		6	204	15,000
Tennessee	23	2		10	133	12,500
Texas	68	8		15	878	72,103
Utah	36	26	22	3	160	7,000
Vermont	14	11	2	8	377	5,282
Virginia	32	8	1	14	345	12,000
Virgin Islands	3			1	13	520
Washington	42	14		11	564	13,765
West Virginia	37	24	2	12	389	15,000
Wisconsin	98	88	68	18	526	55,783
Wyoming	22	10	2	11	171	8,000
Total	2,415	1,265	347	1,059	2,537	853,732

TABLE 3.—*Revenues and additions to equipment, 1925*

North Carolina	15,000.00	15,000.00	155,945.00	2,144.86	43,444.39	844.86	232,379.11	14,661.80	241.29	2,812.30	1,348.00	2,754.65	22,615.29	
North Dakota	15,000.00	15,000.00	178,366.61	-----	75,529.51	11,000.00	294,896.12	2,000.00	253.00	1,981.00	5,636.00	13,320.00	13,320.00	
Ohio	15,000.00	15,000.00	405,675.00	248,073.20	50,041.19	2,375.05	736,164.44	106,883.29	391.62	2,017.76	8,974.01	6,769.91	64,701.61	
Oklahoma	15,000.00	15,000.00	12,500.00	998.48	14,426.04	57,925.32	57,925.81	443.77	765.51	2,140.10	1,785.92	2,140.10	6,088.11	
Oregon	15,000.00	15,000.00	15,600.00	52,454.98	104,500.00	52,454.98	27,932.75	5,289.66	83.01	220.92	4,581.65	7,111.65	425.55	
Pennsylvania	15,000.00	15,000.00	60,408.80	-----	10,906.90	11,236.24	112,551.94	-----	1,007.96	1,666.70	995.07	459.61	944.82	
Porto Rico	-----	-----	-----	-----	-----	56,860.00	-----	-----	-----	-----	-----	-----	-----	-----
Rhode Island	15,000.00	15,000.00	4,516.82	161.45	5,463.22	-----	40,147.49	22.00	292.00	91.00	277.00	90.00	6.00	778.00
South Carolina	15,000.00	15,000.00	72,545.79	2,083.33	41,492.04	-----	146,081.16	2,723.01	888.22	927.49	4,887.93	2,440.55	1,683.83	13,551.03
South Dakota	15,000.00	15,000.00	35,420.00	7,643.50	17,325.26	1,778.74	92,107.50	1,223.31	500.00	-----	-----	-----	1,723.31	2,854.47
Tennessee	15,000.00	15,000.00	33,620.61	-----	17,811.27	-----	81,431.88	-----	283.60	340.18	942.74	1,000.00	287.95	59,986.70
Texas	15,000.00	15,000.00	32,935.23	52,903.34	82,772.56	52,903.34	415,611.63	34,304.64	307.20	962.64	16,410.77	5,855.70	2,145.75	2,145.75
Utah	15,000.00	15,000.00	46,891.71	2,225.76	18,061.31	259.85	97,488.63	800.00	50.00	1,000.00	600.00	600.00	3,650.00	3,650.00
Vermont	15,000.00	15,000.00	12,560.78	65.38	1,000.41	-----	43,626.57	1,114.81	224.06	406.96	300.00	300.00	2,045.83	5,080.48
Virgin Islands ²	15,000.00	15,000.00	8,222.60	-----	9,072.10	616.40	118,067.31	1,596.35	553.86	1,994.09	768.88	167.30	-----	-----
Washington	15,000.00	15,000.00	101,955.82	-----	24,680.00	24,680.00	181,633.18	3,300.00	1,170.22	3,549.03	3,204.97	1,392.28	12,621.50	12,621.50
West Virginia	15,000.00	15,000.00	85,000.00	8,769.48	-----	38,633.22	162,422.70	15,172.46	232.68	1,249.31	5,782.96	4,106.00	1,572.82	28,116.23
Wisconsin	15,000.00	15,000.00	249,244.13	1,794.93	12,500.00	1,794.93	70,773.61	16,337.20	366,354.94	7,724.00	1,743.66	4,024.88	1,888.00	2,335.82
Wyoming	15,000.00	15,000.00	-----	-----	-----	-----	884.37	45,179.30	8,600.00	875.00	700.00	900.00	5,400.00	20,632.36
Total	720,000.00	720,000.00	5,827,871.88	1,041,867.71	427,486.63	1,390,480.48	454,269.17	10,581,975.57	782,789.18	35,379.14	98,956.08	136,887.15	129,313.60	291,876.47
														1,475,201.62

¹ Not including balances from Federal funds.² Supported by direct appropriations to the United States Department of Agriculture.

TABLE 4.—*Expenditures from United States appropriations received under*

Station	Amount of appropriation	Classified expenditures						
		Salaries	Labor	Publications	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies
Alabama	\$15,000.00	\$9,943.36	\$1,948.71	\$6.07	\$285.31	\$45.54		\$214.76
Arizona	15,000.00	15,000.00						
Arkansas	15,000.00	8,065.00	2,392.62	1,091.34	155.14	160.60	\$41.18	194.46
California	15,000.00	15,000.00						
Colorado	15,000.00	14,679.74	27.30		7.40			8.25
Connecticut (State)	7,500.00	7,500.00						
C o n n e c t i c u t (Storrs)	7,500.00	7,500.00						
Delaware	15,000.00	9,770.68	900.53	2,184.56	843.38	4.49	66.32	154.81
Florida	15,000.00	15,000.00						
Georgia	15,000.00	9,292.25	2,940.20	260.11	328.53	74.19	806.70	75.59
Idaho	15,000.00	12,395.38	1,718.82	41.35		7.25	82.76	114.64
Illinois	15,000.00	14,809.37	188.62					
Indiana	15,000.00	14,900.00	100.00					
Iowa	15,000.00	8,415.00	705.46	1,373.20	205.05		53.34	13.26
Kansas	15,000.00	9,700.00	3,965.68	100.00	4.50			158.43
Kentucky	15,000.00	14,873.99						
Louisiana	15,000.00	7,496.95	2,536.28	4.50	55.92	177.70	98.94	
Maine	15,000.00	7,648.08	3,396.41	9.00	232.47	66.77	831.84	61.09
Maryland	15,000.00	14,867.74	125.00		7.26			
Massachusetts	15,000.00	14,750.01						
Michigan	15,000.00	15,000.00						
Minnesota	15,000.00	15,000.00						
Mississippi	15,000.00	9,222.00	3,154.59		1.00	206.69	37.26	
Missouri	15,000.00	6,855.67	3,853.07		210.15	269.52	61.58	103.47
Montana	15,000.00	14,193.33	39.91	464.33		5.58		71.52
Nebraska	15,000.00	15,000.00						
Nevada	15,000.00	10,305.07	1,914.85	291.60	196.57	32.86	46.75	38.95
New Hampshire	15,000.00	10,789.75	413.80	474.80	465.90	307.56	600.00	115.09
New Jersey	15,000.00	10,603.00	894.01	153.00	250.16	16.95	200.40	211.47
New Mexico	15,000.00	7,868.57	3,105.60	1,123.57	135.23	90.24	257.69	89.55
New York (State)	1,500.00	837.50	662.50					
New York (Cornell)	13,500.00	6,178.87	4,620.50	30.10	215.60	63.44	36.40	265.42
North Carolina	15,000.00	13,011.58	1,096.36		250.46	17.78	11.00	
North Dakota	15,000.00	15,000.00						
Ohio	15,000.00	8,093.32	3,350.80		258.50		800.53	
Oklahoma	15,000.00	4,630.00	4,372.34	635.58	122.48	162.08	81.25	159.83
Oregon	15,000.00	10,884.17	2,168.46	481.71	6.13	7.89	8.35	130.84
Pennsylvania	15,000.00	11,800.00	772.38	1,687.75	5.27	103.94	43.00	15.56
Rhode Island	15,000.00	6,206.75	4,604.33	808.47	167.33	236.30	267.86	29.68
South Carolina	15,000.00	8,024.97	1,958.59	524.83	711.83	91.53		27.34
South Dakota	15,000.00	7,899.90	3,175.06	833.43	125.66	24.80		655.07
Tennessee	15,000.00	11,205.00	1,693.01	327.02	251.87	67.32	671.84	26.01
Texas	15,000.00	12,174.88	1,209.97		294.98			
Utah	15,000.00	10,321.00	2,070.80	553.18	78.14	14.27	41.05	58.21
Vermont	15,000.00	6,534.99	2,030.49	2,543.66	230.71	33.15	1,069.57	261.49
Virginia	15,000.00	10,169.92	1,948.47	402.50	318.68	126.43	70.22	101.90
Washington	15,000.00	10,505.20	1,613.60	1,560.46	74.56			50.91
West Virginia	15,000.00	8,787.46	2,707.06		25.55			238.82
Wisconsin	15,000.00	10,000.00	1,848.20	295.79			.64	
Wyoming	15,000.00	14,280.00	720.00					1,006.22
Total	720,000.00	532,990.45	76,944.38	18,261.91	6,521.72	2,415.51	6,285.83	4,652.64

the act of March 2, 1887 (Hatch Act), for the year ended June 30, 1925

Classified expenditures										
Seeds, plants, and sundry supplies	Ferti- lizers	Feeding stuffs	Library	Tools, im- ple- ments, and ma- chinery	Furni- ture and fixtures	Sci- entific ap- paratus	Live- stock	Traveling expenses	Conti- nent ex- penses	Build- ings and land
\$427.13	\$564.05	\$373.20	\$299.39	\$241.76	\$127.68	\$184.54	-----	\$334.10	-----	\$4.40
716.95	22.71	660.18	92.14	141.71	257.08	236.24	\$181.61	452.98	-----	138.06
9.00	-----	-----	42.11	-----	-----	226.20	-----	-----	-----	-----
200.21	129.80	-----	268.99	15.10	70.87	4.61	-----	385.65	-----	-----
307.19	509.68	111.00	16.91	129.70	4.50	-----	-----	113.45	-----	-----
151.09	112.02	13.00	5.50	-----	-----	-----	-----	328.19	-----	30.00
2.01	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
683.37	128.57	3,189.14	-----	103.90	-----	57.40	-----	72.31	-----	-----
40.55	-----	5.00	452.25	25.04	259.11	-----	-----	289.44	-----	-----
796.56	741.97	521.85	78.35	1,055.09	55.75	-----	728.00	282.50	\$126.00	243.64
101.51	235.20	1,464.95	446.89	72.26	54.71	63.65	-----	279.52	-----	35.65
-----	-----	-----	-----	-----	-----	-----	-----	249.99	-----	-----
365.83	241.43	1,515.63	-----	33.53	-----	19.50	-----	149.68	-----	52.86
650.90	23.25	2,105.40	1.78	243.39	11.00	75.28	301.63	67.50	.10	166.31
45.41	-----	-----	-----	-----	-----	21.50	-----	158.42	-----	-----
274.90	66.00	86.96	220.36	34.60	399.98	-----	200.00	738.71	-----	151.84
121.25	134.04	-----	458.19	236.65	261.00	3.60	-----	618.37	-----	-----
274.01	360.00	24.29	32.60	78.53	53.15	-----	-----	1,771.07	14.26	63.10
471.39	41.75	668.35	-----	373.60	63.88	1.64	115.05	593.89	-----	-----
472.84	257.91	23.97	11.00	540.07	128.59	-----	-----	228.22	-----	427.07
285.95	-----	68.95	-----	-----	4.00	-----	-----	253.92	-----	-----
216.34	22.50	2,202.24	-----	-----	-----	-----	-----	55.77	-----	-----
815.49	649.93	293.73	593.97	517.85	234.05	-----	-----	1,632.89	-----	98.53
197.37	128.50	193.67	2.00	19.04	18.40	-----	-----	753.47	-----	-----
105.08	346.52	-----	100.93	-----	-----	-----	-----	7.32	-----	12.25
387.68	965.70	308.32	217.65	268.97	12.35	-----	90.00	237.22	32.17	159.22
350.28	300.00	933.54	697.77	123.24	680.33	21.00	-----	480.11	-----	74.64
371.81	-----	498.25	-----	192.33	575.03	246.16	402.50	-----	-----	-----
110.07	6.90	-----	257.71	72.47	35.55	10.43	-----	81.35	1.21	182.24
-----	-----	325.49	24.10	31.40	300.00	50.00	548.86	-----	40.32	-----
368.24	981.22	46.03	1.95	59.88	-----	-----	-----	240.35	15.00	150.68
306.67	129.25	168.53	185.06	159.21	7.07	92.73	-----	498.27	1.35	747.80
553.51	323.47	103.94	155.10	104.99	87.30	101.07	110.00	162.83	20.00	139.67
79.81	9.63	-----	49.00	16.00	-----	156.11	-----	884.72	-----	-----
1,020.44	76.56	-----	4.50	278.77	-----	259.44	-----	1,589.38	-----	12.02
256.65	59.37	-----	-----	68.68	416.50	939.86	-----	108.09	-----	-----
11,537.49	5,464.76	17,626.73	3,911.05	5,743.66	4,252.87	3,317.27	2,677.65	14,255.69	210.09	2,930.30

TABLE 5.—*Expenditures from United States appropriations received under*

Station	Amount of appropriation	Classified expenditures					
		Salaries	Labor	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies
Alabama	\$15,000.00	\$11,011.83	\$757.95	\$163.17	\$182.62	\$112.73	\$97.45
Arizona	15,000.00	12,611.97	277.69	2.70	9.53	—	231.88
Arkansas	15,000.00	9,200.00	2,818.49	1.07	70.54	75.34	559.83
California	15,000.00	15,000.00	—	—	—	—	—
Colorado	15,000.00	14,373.55	134.70	16.34	.50	—	25.07
Connecticut (State)	7,500.00	7,500.00	—	—	—	—	—
Connecticut (Storrs)	7,500.00	7,500.00	—	—	—	—	—
Delaware	15,000.00	11,694.17	315.30	17.42	41.95	—	1,398.14
Florida	15,000.00	15,000.00	—	—	—	—	—
Georgia	15,000.00	11,070.83	522.36	13.40	162.71	445.54	805.30
Idaho	15,000.00	11,718.37	988.91	—	.47.65	72.81	746.56
Illinois	15,000.00	13,026.60	1,973.40	—	—	—	—
Indiana	15,000.00	11,915.00	358.65	36.45	22.45	—	375.50
Iowa	15,000.00	9,395.00	2,298.79	69.17	9.76	38.21	1,346.48
Kansas	15,000.00	10,300.00	3,619.30	3.36	12.09	—	261.43
Kentucky	15,000.00	14,960.21	—	—	—	—	—
Louisiana	15,000.00	12,606.20	1,008.77	76.16	10.88	74.09	134.37
Maine	15,000.00	15,000.00	—	—	—	—	—
Maryland	15,000.00	13,887.62	214.00	54.34	2.20	—	487.37
Massachusetts	15,000.00	15,000.00	—	—	—	—	—
Michigan	15,000.00	15,000.00	—	—	—	—	—
Minnesota	15,000.00	15,000.00	—	—	—	—	—
Mississippi	15,000.00	12,399.84	1,839.32	—	17.62	102.50	—
Missouri	15,000.00	3,245.32	3,410.80	131.73	327.76	285.87	1,883.45
Montana	15,000.00	10,470.96	2,247.67	65.79	7.48	2.00	419.57
Nebraska	15,000.00	15,000.00	—	—	—	—	—
Nevada	15,000.00	7,900.00	3,249.25	14.20	43.85	173.46	227.52
New Hampshire	15,000.00	11,630.00	899.08	38.62	121.81	—	341.58
New Jersey	15,000.00	12,885.00	87.18	13.53	3.92	756.27	711.85
New Mexico	15,000.00	9,334.16	3,637.76	60.97	155.58	446.43	150.70
New York (State)	1,500.00	1,500.00	—	—	—	—	—
New York (Cornell)	13,500.00	10,682.24	1,667.68	34.16	22.75	—	875.15
North Carolina	15,000.00	12,366.01	948.04	61.36	29.55	17.38	581.59
North Dakota	15,000.00	15,000.00	—	—	—	—	—
Ohio	15,000.00	11,500.00	2,373.06	6.95	—	—	—
Oklahoma	15,000.00	10,180.00	1,860.18	26.04	11.15	—	489.45
Oregon	15,000.00	13,650.01	647.36	18.11	46.46	56.97	467.03
Pennsylvania	15,000.00	12,933.60	636.95	6.69	34.45	7.18	445.15
Rhode Island	15,000.00	9,591.78	2,311.62	30.84	17.55	670.75	153.96
South Carolina	15,000.00	10,691.05	1,679.23	263.82	38.39	225.00	229.53
South Dakota	15,000.00	7,841.58	5,462.62	45.71	14.57	—	500.64
Tennessee	15,000.00	13,680.00	40.30	16.15	70.83	128.37	570.46
Texas	15,000.00	13,344.84	827.31	58.08	16.10	—	406.26
Utah	15,000.00	10,299.96	2,950.90	33.68	56.73	—	646.08
Vermont	15,000.00	9,716.67	2,810.05	44.16	21.83	229.51	207.14
Virginia	15,000.00	11,236.99	2,764.73	2.80	86.66	—	92.02
Washington	15,000.00	11,370.91	1,761.80	10.00	—	—	412.22
West Virginia	15,000.00	12,176.61	429.12	90.60	1.25	—	133.58
Wisconsin	15,000.00	9,720.00	3,662.63	—	12.89	—	276.29
Wyoming	15,000.00	13,979.75	1,020.25	—	—	—	—
Total	720,000.00	577,098.63	64,513.20	1,527.57	1,732.06	3,920.41	16,690.60

the act of March 16, 1906 (Adams Act), for the year ended June 30, 1925

Classified expenditures

Seeds, plants, and sundry supplies	Ferti- lizers	Feeding stuffs	Library	Tools, imple- ments, and ma- chinery	Furni- ture and fixtures	Sci- entific appa- ratus	Livestock	Travel- ing expenses	Conting- ent ex- penses	Build- ings and land
\$619.54	\$24.22	\$751.55	\$127.53	\$519.54	\$50.79	\$581.08	-----	-----	-----	-----
280.98	-----	-----	-----	6.15	-----	921.91	-----	\$657.19	-----	-----
436.00	7.25	378.38	-----	4.13	-----	1,061.68	\$43.50	240.63	-----	\$103.16
12.66	-----	10.40	19.70	.80	-----	284.83	-----	121.45	-----	-----
296.00	-----	-----	61.34	-----	-----	873.78	-----	301.90	-----	-----
63.00	66.00	1,282.15	67.12	71.12	-----	25.69	234.36	170.42	-----	-----
54.36	122.25	114.70	-----	1.00	-----	82.41	-----	1,050.98	-----	-----
288.73	-----	-----	18.14	26.05	40.72	915.26	773.00	190.05	-----	40.00
483.51	684.14	-----	-----	11.19	-----	408.93	-----	254.82	-----	-----
47.89	417.42	-----	3.38	10.43	.6.00	21.04	22.50	103.18	-----	161.98
132.64	-----	64.35	48.49	7.10	6.00	679.06	30.00	106.89	-----	15.00
28.38	-----	-----	1.00	28.00	24.70	252.71	-----	13.05	-----	6.63
99.24	7.00	-----	35.35	39.35	-----	341.95	-----	117.83	-----	-----
458.44	12.52	2,850.23	5.00	962.31	139.13	508.19	122.30	106.72	\$70.00	480.23
102.45	-----	-----	153.83	10.35	-----	603.16	-----	916.74	-----	-----
40.63	-----	1,502.90	3.15	10.00	-----	703.97	581.83	549.24	-----	-----
109.89	384.86	-----	414.76	67.70	-----	254.38	-----	42.38	-----	694.94
110.15	-----	-----	4.95	2.25	-----	372.36	-----	30.34	3.34	18.86
126.91	124.23	529.74	-----	191.45	81.77	56.24	63.00	10.06	-----	31.00
108.71	-----	-----	7.32	-----	-----	76.99	-----	-----	-----	25.00
76.79	193.04	-----	-----	-----	-----	450.03	-----	276.21	-----	-----
-----	-----	83.67	-----	-----	-----	1,036.32	-----	-----	-----	-----
473.62	5.65	806.26	99.95	151.09	137.75	498.37	172.05	26.74	-----	61.70
37.62	-----	18.10	3.00	55.34	-----	-----	-----	-----	-----	-----
11.50	136.00	-----	116.40	31.04	3.00	586.97	-----	48.79	2.28	-----
123.76	1,697.53	-----	38.75	115.70	1.70	81.24	17.50	-----	-----	147.32
184.97	300.00	-----	102.67	440.59	436.50	312.35	-----	39.40	-----	56.50
272.51	26.20	60.45	-----	69.84	340.75	217.91	80.00	55.89	-----	11.33
44.61	-----	-----	39.55	13.70	19.16	116.18	-----	136.39	2.38	121.92
47.57	-----	-----	142.38	-----	-----	5.63	100.00	-----	-----	51.81
203.05	-----	8.50	58.53	7.75	-----	394.81	-----	262.30	-----	77.71
292.82	24.10	567.31	26.25	63.88	44.62	171.48	300.00	158.88	13.79	307.51
71.62	-----	303.05	-----	8.60	21.15	407.88	-----	4.50	-----	4.50
431.09	-----	-----	12.29	45.00	107.33	410.50	-----	438.86	-----	-----
147.30	-----	193.29	-----	102.31	-----	1,530.71	-----	195.23	-----	-----
101.03	-----	951.15	-----	35.48	-----	236.03	-----	4.50	-----	-----
6,419.97	1,048.46	13,651.63	837.56	3,802.96	1,559.12	15,482.05	2,540.04	6,666.85	91.79	2,417.10

TABLE 6.—*Disbursements from the United States Treasury to the States and Territories for agricultural experiment stations under the acts of Congress approved March 2, 1887, and March 16, 1906*

State or Territory	Hatch Act		Adams Act	
	1888-1924	1925	1906-1924	1925
Alabama	\$553,956.42	\$15,000.00	\$251,619.89	\$15,000.00
Arizona	519,803.10	15,000.00	254,955.61	15,000.00
Arkansas	553,139.12	15,000.00	254,900.00	15,000.00
California	555,000.00	15,000.00	254,926.84	15,000.00
Colorado	554,718.82	15,000.00	253,638.93	15,000.00
Connecticut	555,000.00	15,000.00	255,000.00	15,000.00
Dakota Territory	55,250.00			
Delaware	553,382.87	15,000.00	250,475.12	15,000.00
Florida	554,966.04	15,000.00	254,996.06	15,000.00
Georgia	550,593.43	15,000.00	242,092.87	15,000.00
Idaho	479,324.13	15,000.00	250,842.22	15,000.00
Illinois	554,564.95	15,000.00	254,851.62	15,000.00
Indiana	554,901.19	15,000.00	255,000.00	15,000.00
Iowa	555,000.00	15,000.00	255,000.00	15,000.00
Kansas	504,995.00	15,000.00	255,000.00	15,000.00
Kentucky	554,996.57	15,000.00	255,000.00	15,000.00
Louisiana	555,000.00	15,000.00	255,000.00	15,000.00
Maine	554,999.62	15,000.00	255,000.00	15,000.00
Maryland	554,967.40	15,000.00	254,236.48	15,000.00
Massachusetts	554,617.70	15,000.00	255,000.00	15,000.00
Michigan	554,676.10	15,000.00	251,341.20	15,000.00
Minnesota	554,917.78	15,000.00	254,345.00	15,000.00
Mississippi	555,000.00	15,000.00	255,000.00	15,000.00
Missouri	550,097.24	15,000.00	254,999.90	15,000.00
Montana	465,000.00	15,000.00	252,417.04	15,000.00
Nebraska	554,932.16	15,000.00	255,000.00	15,000.00
Nevada	554,214.32	15,000.00	253,180.28	15,000.00
New Hampshire	555,000.00	15,000.00	255,000.00	15,000.00
New Jersey	554,949.97	15,000.00	254,392.06	15,000.00
New Mexico	519,509.05	15,000.00	255,000.00	15,000.00
New York	554,757.18	15,000.00	254,463.01	15,000.00
North Carolina	555,000.00	15,000.00	240,000.00	15,000.00
North Dakota	496,502.26	15,000.00	254,638.85	15,000.00
Ohio	555,000.00	15,000.00	253,514.02	15,000.00
Oklahoma	479,002.16	15,000.00	234,535.19	15,000.00
Oregon	540,156.64	15,000.00	250,000.00	15,000.00
Pennsylvania	554,967.43	15,000.00	254,995.41	15,000.00
Rhode Island	555,000.00	15,000.00	252,464.20	15,000.00
South Carolina	554,542.15	15,000.00	253,460.12	15,000.00
South Dakota	498,250.00	15,000.00	250,000.00	15,000.00
Tennessee	555,000.00	15,000.00	255,000.00	15,000.00
Texas	555,000.00	15,000.00	252,592.26	15,000.00
Utah	420,000.00	15,000.00	254,821.94	15,000.00
Vermont	555,000.00	15,000.00	255,000.00	15,000.00
Virginia	552,824.12	15,000.00	254,949.01	15,000.00
Washington	492,102.65	15,000.00	251,080.11	15,000.00
West Virginia	554,968.71	15,000.00	252,859.12	15,000.00
Wisconsin	555,000.00	15,000.00	255,000.00	15,000.00
Wyoming	540,000.00	15,500.00	255,000.00	15,000.00
Total	26,021,546.28	720,000.00	12,142,584.36	720,000.00



ADDRESS LIST OF AGRICULTURAL EXPERIMENT STATIONS

ALABAMA.—*Auburn*, M. J. Funchess, Director.
ALASKA.—*Sitka*, C. C. Georgeson, Director.
ARIZONA.—*Tucson*, J. J. Thornber, Director.
ARKANSAS.—*Fayetteville*, Dan T. Gray, Director.
CALIFORNIA.—*Berkeley*, E. D. Merrill, Director.
COLORADO.—*Fort Collins*, C. P. Gillette, Director.
CONNECTICUT.—*New Haven*, W. L. Slate, jr., Director; *Storrs*, W. L. Slate, jr., Director.
DELAWARE.—*Newark*, C. A. McCue, Director.
FLORIDA.—*Gainesville*, Wilmon Newell, Director.
GEORGIA.—*Experiment*, H. P. Stuckey, Director.
GUAM.—*Guam*, C. W. Edwards, Director.
HAWAII.—*Honolulu*, J. M. Westgate, Director.
IDAHO.—*Moscow*, E. J. Iddings, Director.
ILLINOIS.—*Urbana*, H. W. Mumford, Director.
INDIANA.—*La Fayette*, G. I. Christie, Director.
IOWA.—*Ames*, C. F. Curtiss, Director.
KANSAS.—*Manhattan*, L. E. Call, Director.
KENTUCKY.—*Lexington*, T. P. Cooper, Director.
LOUISIANA.—*Baton Rouge*, W. R. Dodson, Director.
MAINE.—*Orono*, W. J. Morse, Director.
MARYLAND.—*College Park*, H. J. Patterson, Director.
MASSACHUSETTS.—*Amherst*, S. B. Haskell, Director.
MICHIGAN.—*East Lansing*, R. S. Shaw, Director.
MINNESOTA.—*University Farm*, St. Paul, W. C. Coffey, Director.
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